

POPULAR MECHANICS

JUNE 1971
50 CENTS



Build This Safe, Simple
Scuba

Sub:
\$400

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Vandals? Prowlers?

Our \$30 'House Watcher' Stops 'Em Page 120

What Your '72 Car Will Look Like

Gremlin and Dart Owners: 'Great on Mileage, BUT—'

Dream Workshop
Full of Ideas for You

10 Steps to a
Crystal-Clear Pool

Build This TWO-MAN SUB for \$400



The submariner's world is like nothing you've ever experienced. And the thrill is even greater when you build the boat yourself!

By W. KENT MARKHAM

Photos by Bruce Mozart

LET ME PUT YOU in the driver's seat of a new mini-sub for the next few minutes. First, visualize the crystal clear water of Silver Springs, Fla.: about 100 yards wide and 65 feet deep at the main spring, which flows from an underground cave.

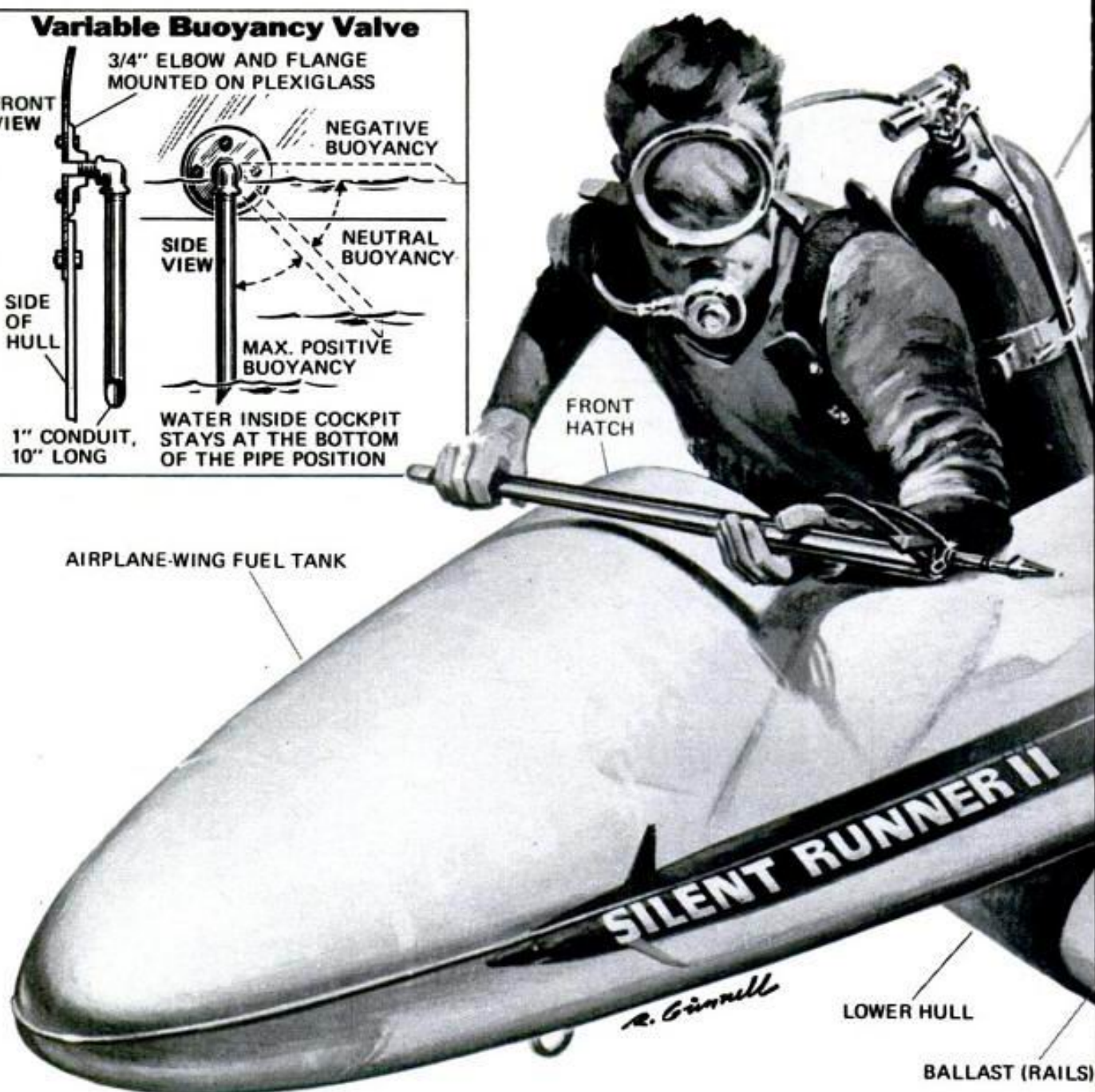
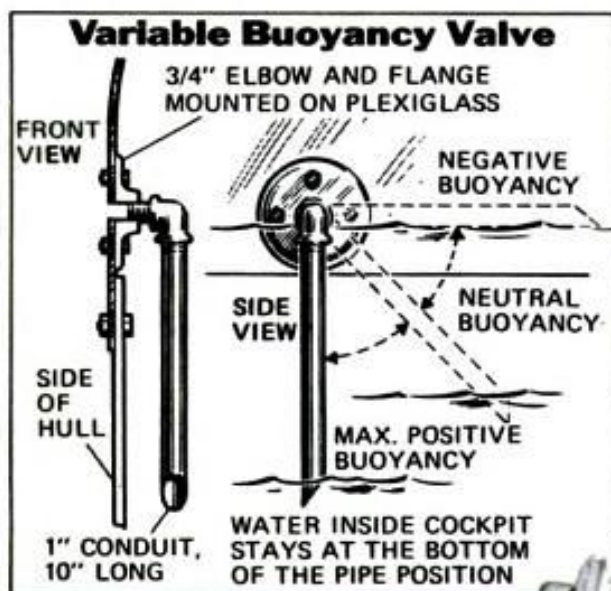
Once you have been checked out on the basic operating procedures of the sub, you wade out to the surfaced craft. Then, after reaching down and opening the entry hatch, you fill your lungs with air, lower your body underwater and swim into the opening. Once your head pops up inside, you find yourself in an air pocket. Next, you straddle the battery compartment and pull the adjustable seat back to a comfortable position.

Your diving buddy removes the forward hatch and climbs aboard wearing full scuba gear—he must since he rides outside. The skipper, however, is inside the air pocket and out of water from the waist up. When your buddy motions that he is ready, you grab the control handles and flip on both motor switches. Instantly the sub responds with a slight lunge forward, and within several seconds you are moving along at four to five mph.

When the controls are moved forward (tilting the motors), a lot of propwash is kicked up. The craft strains to go under, but it is much too buoyant. To counter this you use the variable buoyancy valve on the right side. When the pipe is brought up to a 45° angle, you'll hear much gurgling and notice the sub getting

HULL IS DISCARDED FUEL TANK; other materials were purchased locally. Skipper (below, right) is half in and half out of water in the airtight cockpit, while his buddy rides outside (see opposite page)



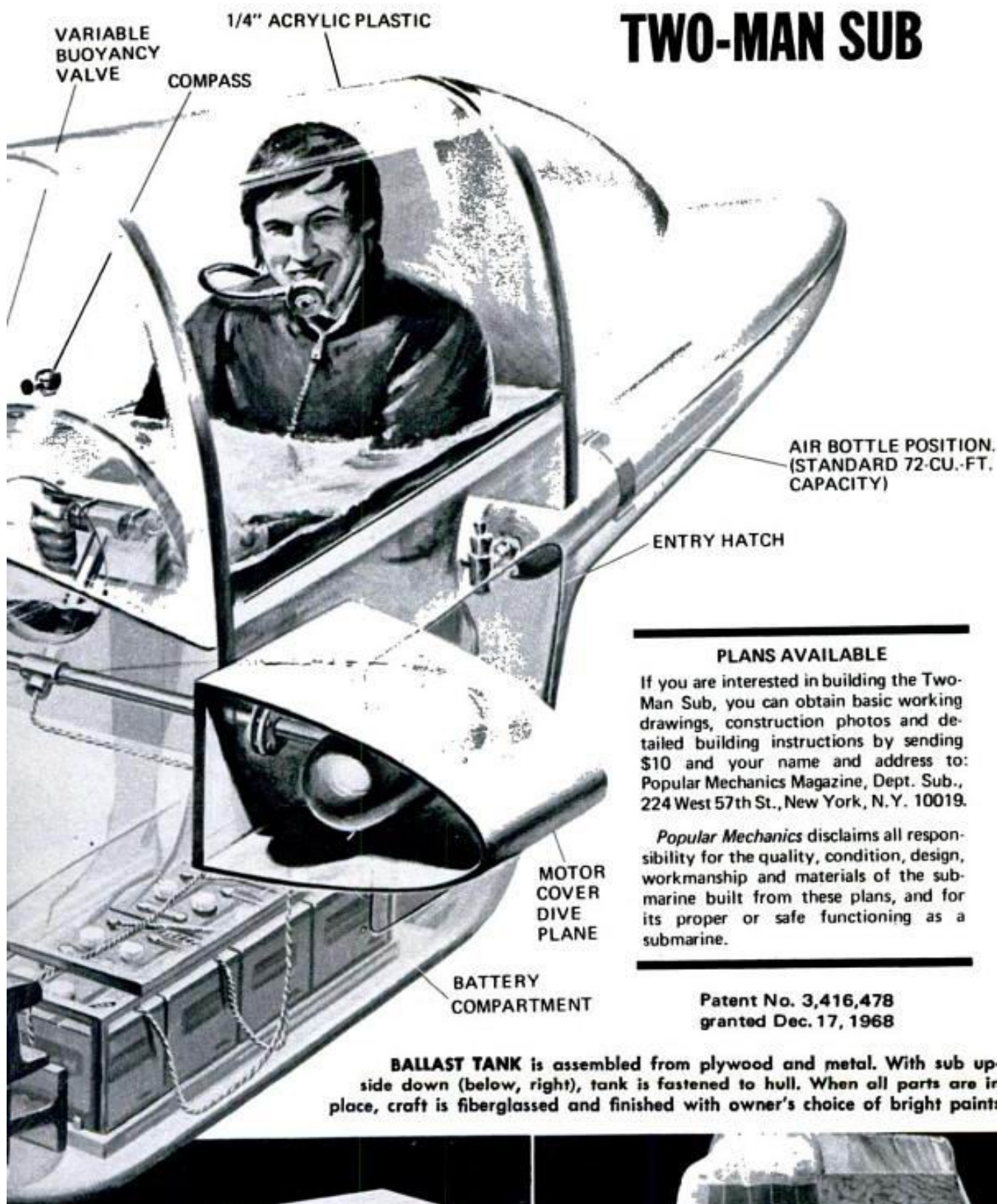


lower and lower in the water. Air bubbles pour out of the side, and for a second you wonder if something is wrong. For the first few seconds underwater, hundreds of tiny air bubbles rise off the entire hull surface, but they quickly disappear.

In these waters, your first reaction is likely to be to the fantastic beauty of the springs. The subtle shades of blue and green against a white sand bottom are breathtaking.

Your buddy riding up front acts as a
(Please turn to page 172)

TWO-MAN SUB



PLANS AVAILABLE

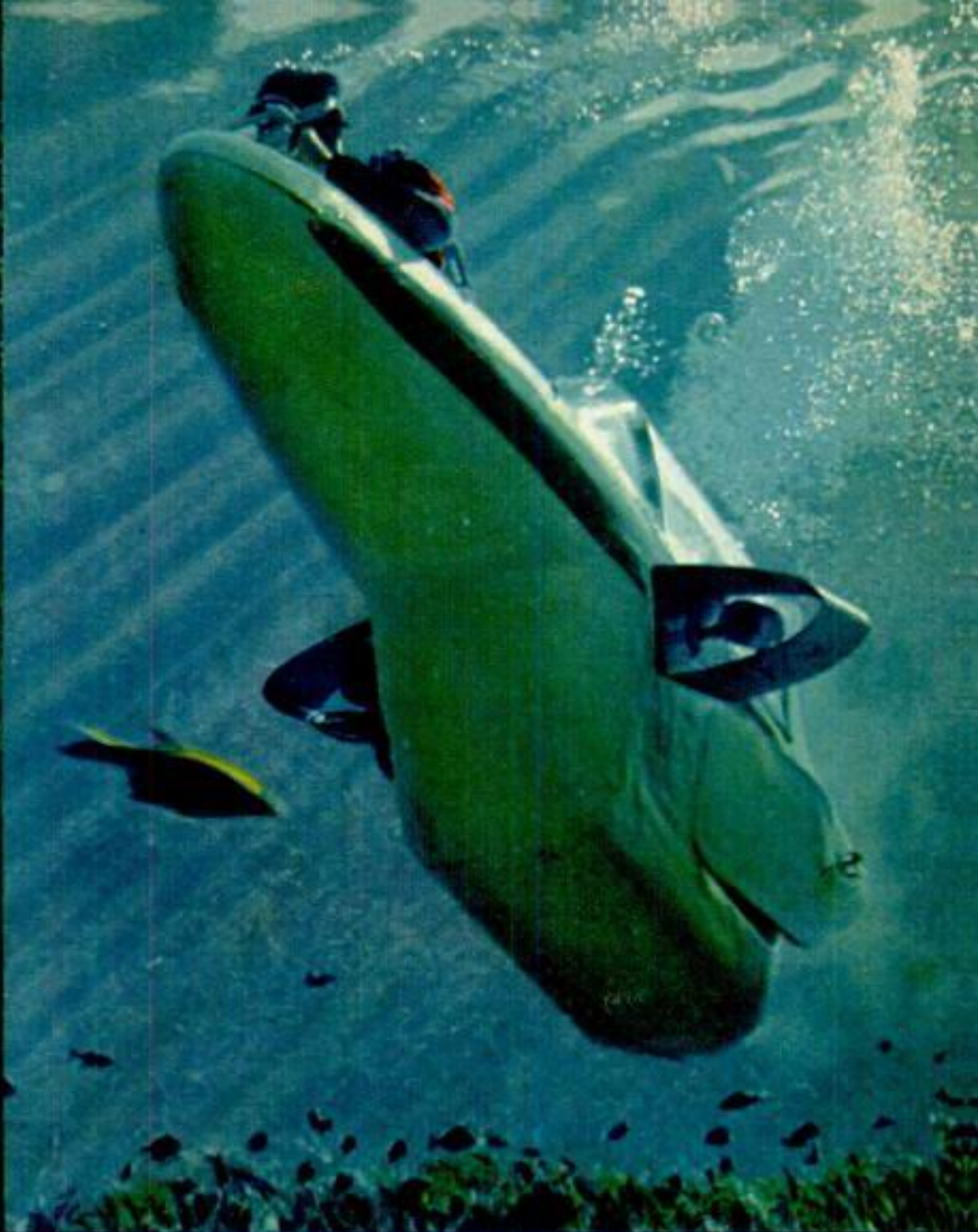
If you are interested in building the Two-Man Sub, you can obtain basic working drawings, construction photos and detailed building instructions by sending \$10 and your name and address to: Popular Mechanics Magazine, Dept. Sub., 224 West 57th St., New York, N.Y. 10019.

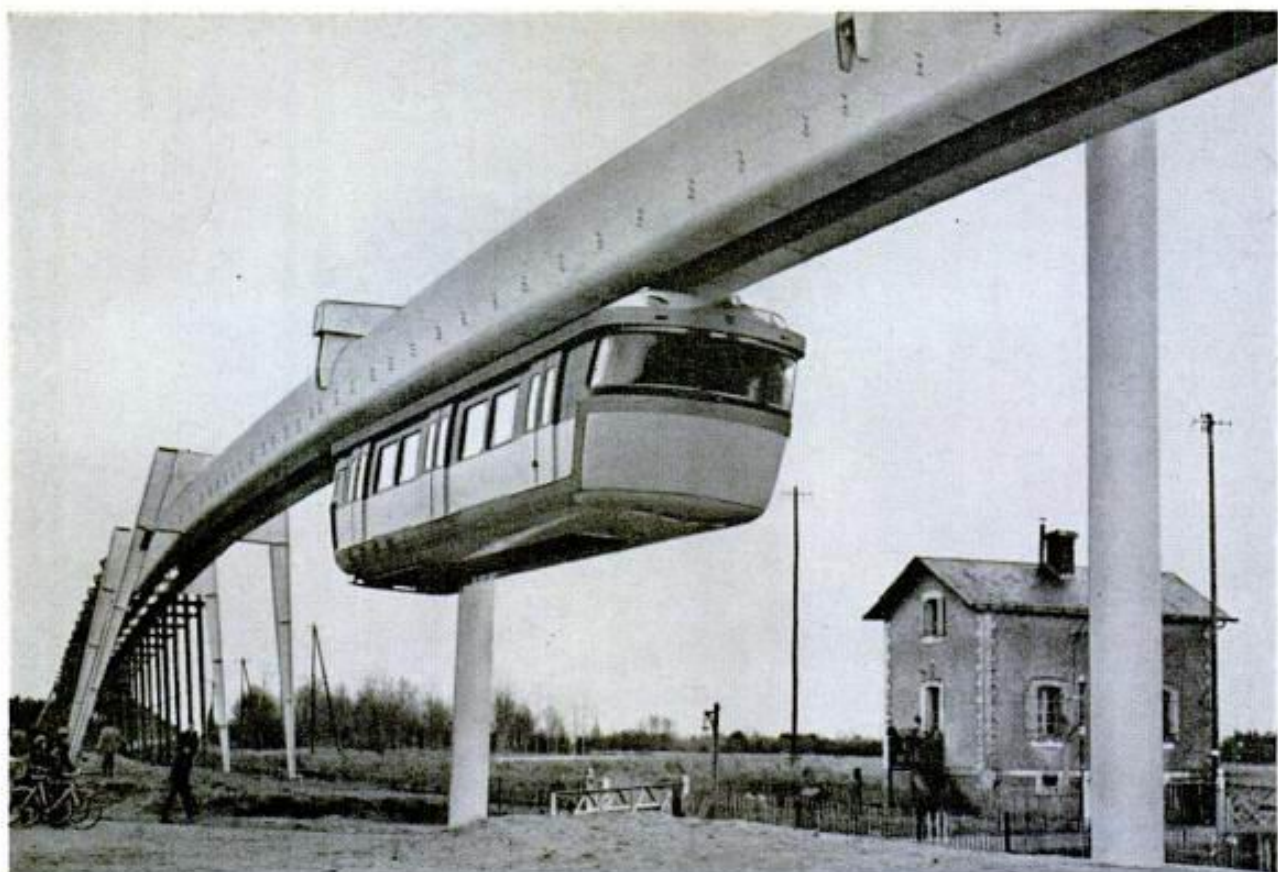
Popular Mechanics disclaims all responsibility for the quality, condition, design, workmanship and materials of the submarine built from these plans, and for its proper or safe functioning as a submarine.

Patent No. 3,416,478
granted Dec. 17, 1968

BALLAST TANK is assembled from plywood and metal. With sub upside down (below, right), tank is fastened to hull. When all parts are in place, craft is fiberglassed and finished with owner's choice of bright paints



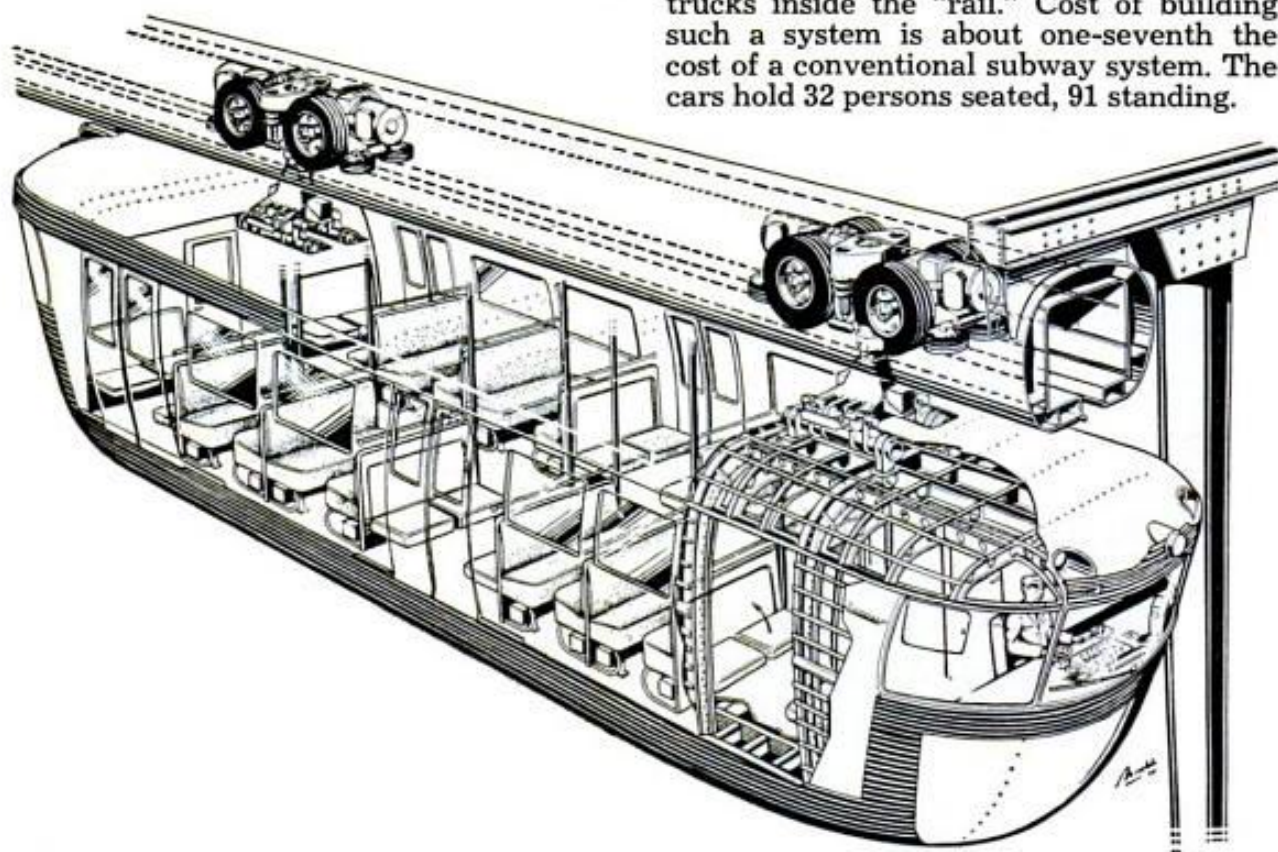




French Monorail Train Rolls Quietly on Pneumatic Tires

Fast, quiet and relatively inexpensive to build, a French monorail system of urban transportation may help solve the problem of mass transit. Built by Renault as a test program, the monorail operates on a demonstration track just over a half-mile long

near Orleans, France. Operating speed of the electric-powered car is about 60 miles per hour. Eight pneumatic-tired wheels carry the weight of the car, rolling quietly inside a box girder. Eight smaller wheels are mounted horizontally to position the trucks inside the "rail." Cost of building such a system is about one-seventh the cost of a conventional subway system. The cars hold 32 persons seated, 91 standing.



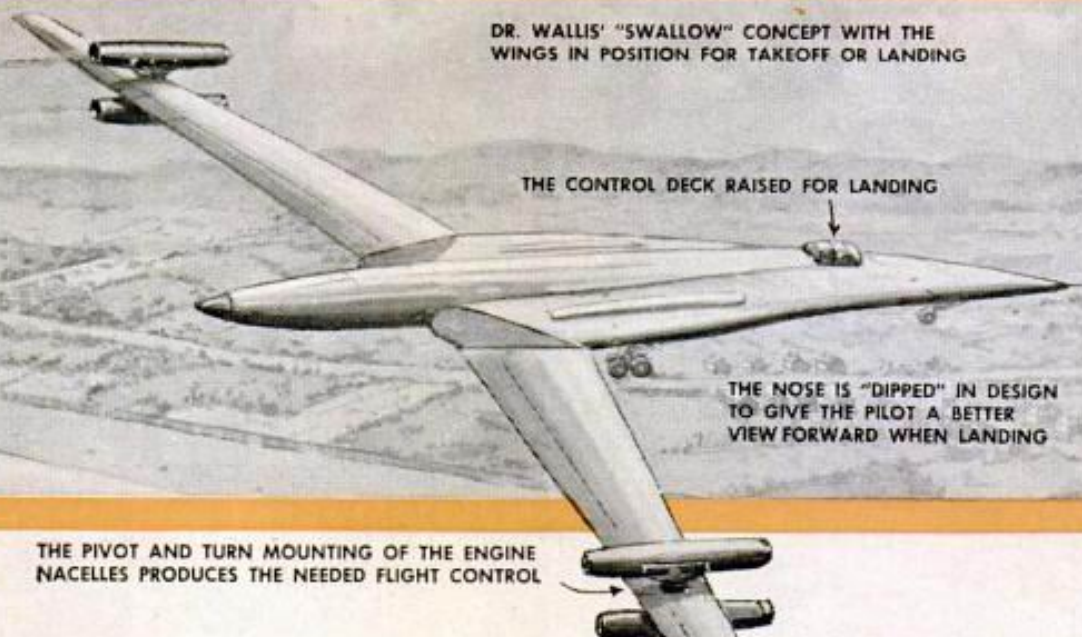
TO SECURE EARLY DATA, A SERIES OF EXPERIMENTS WERE CARRIED OUT WITH A LARGE PILOTLESS MODEL LAUNCHED FROM A ROCKET-PROPELLED TROLLEY. THE AIRCRAFT HAD A WINGSPAN OF 30 FEET AND WAS POWERED BY TWO ROCKET MOTORS AND RADIO CONTROLLED. THESE TESTS PROVED THE PRACTICABILITY OF THE REAR WING POSITION AND THAT THE AIRPLANE COULD BE MANEUVERED WITHOUT THE USE OF TAILPLANE OR AILERONS BY A SIMPLE MOVEMENT OF THE WINGS



WHEN THE FUSELAGE IS LONG OR WINGS STEEPLY SWEEPED, AS THEY HAVE TO BE FOR SUPERSONIC FLIGHT, A PROBLEM IS CREATED AT TAKEOFF AND LANDING: THE UNDERCARRIAGE LEGS WOULD HAVE TO BE IMPOSSIBLY LONG TO GIVE THE NECESSARY GROUND CLEARANCE



DR. WALLIS' "SWALLOW" CONCEPT WITH THE WINGS IN POSITION FOR TAKEOFF OR LANDING



THE CONTROL DECK RAISED FOR LANDING

THE NOSE IS "DIPPED" IN DESIGN TO GIVE THE PILOT A BETTER VIEW FORWARD WHEN LANDING

THE PIVOT AND TURN MOUNTING OF THE ENGINE NACELLES PRODUCES THE NEEDED FLIGHT CONTROL

Movable-Wing Plane

MAN'S ATTEMPTS TO FLY like birds—by flapping his arms or some winglike contrivance—usually end in disaster. A variation on that ancient approach, however, may solve some problems involved in supersonic flight and help man to swoosh through the air at a feather-singeing speed of 1800 miles an hour.

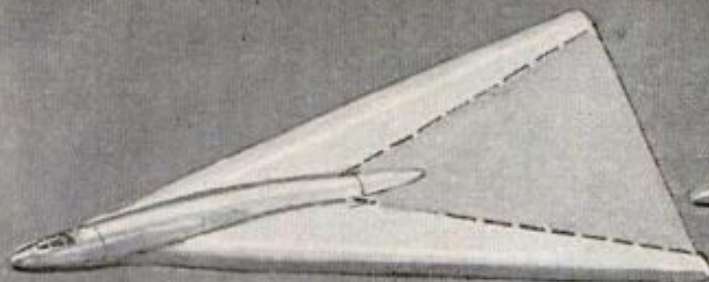
Dr. Barnes Wallis, English airship in-

ventor and chief development scientist at Vickers-Armstrong, has designed a movable-wing plane—appropriately called the "Swallow"—that is thought capable of such speeds. Wings move forward and backward, rather than up and down, to give it high performance capabilities at both supersonic and landing-takeoff speeds.

(Continued to page 251)

POPULAR MECHANICS

IT IS KNOWN THAT WITH DELTA-WING AIRCRAFT, THE HIGH LIFT IS PRODUCED NEAR THE FORWARD EDGES OF THE WINGS. THE CENTER PORTION, HOWEVER, HAS POOR LIFT AND PRODUCES CONSIDERABLE DRAG



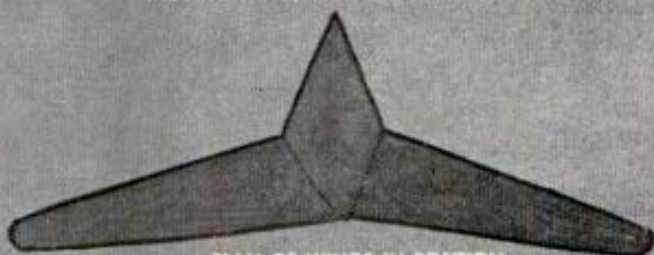
CENTER PORTION
HAVING POOR LIFT
AND CONSIDERABLE DRAG



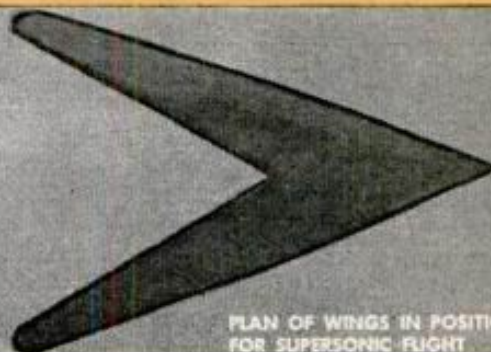
CENTER PORTION
REMOVED

EXPERIMENTS PROVED THAT THIS TYPE OF
WING CONFIGURATION HAD AN EXCELLENT
LIFT/DRAG RATIO FOR SUPERSONIC SPEEDS

AN EARLY DESIGN BY DR. BARNES WALLIS OF A
MOVING-WING, VARIABLE-GEOMETRY AIRCRAFT

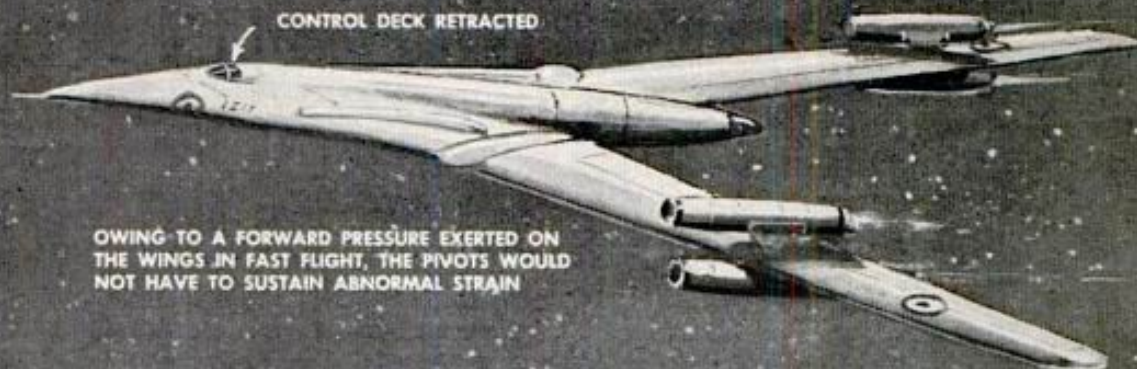


PLAN OF WINGS IN POSITION
FOR TAKEOFF AND LANDING



PLAN OF WINGS IN POSITION
FOR SUPERSONIC FLIGHT

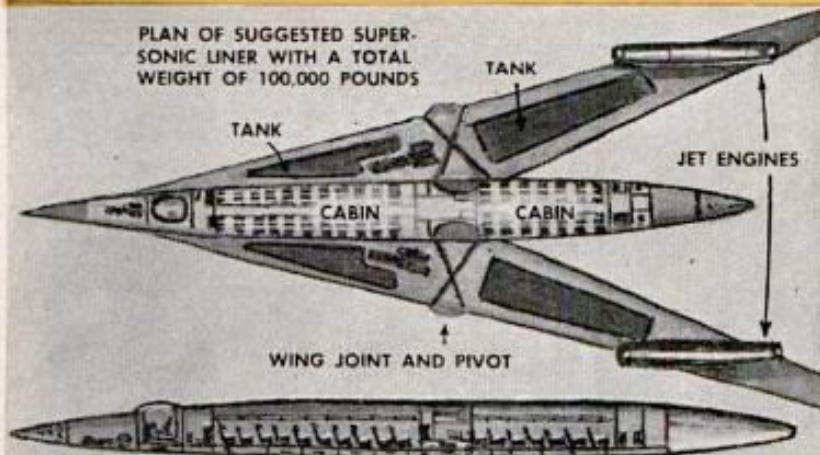
THE WINGS IN POSITION FOR SUPERSONIC FLIGHT



CONTROL DECK RETRACTED

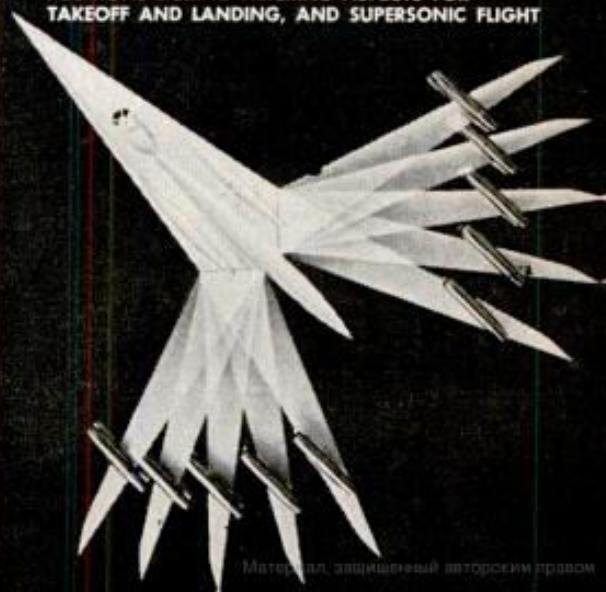
OWING TO A FORWARD PRESSURE EXERTED ON
THE WINGS IN FAST FLIGHT, THE PIVOTS WOULD
NOT HAVE TO SUSTAIN ABNORMAL STRAIN

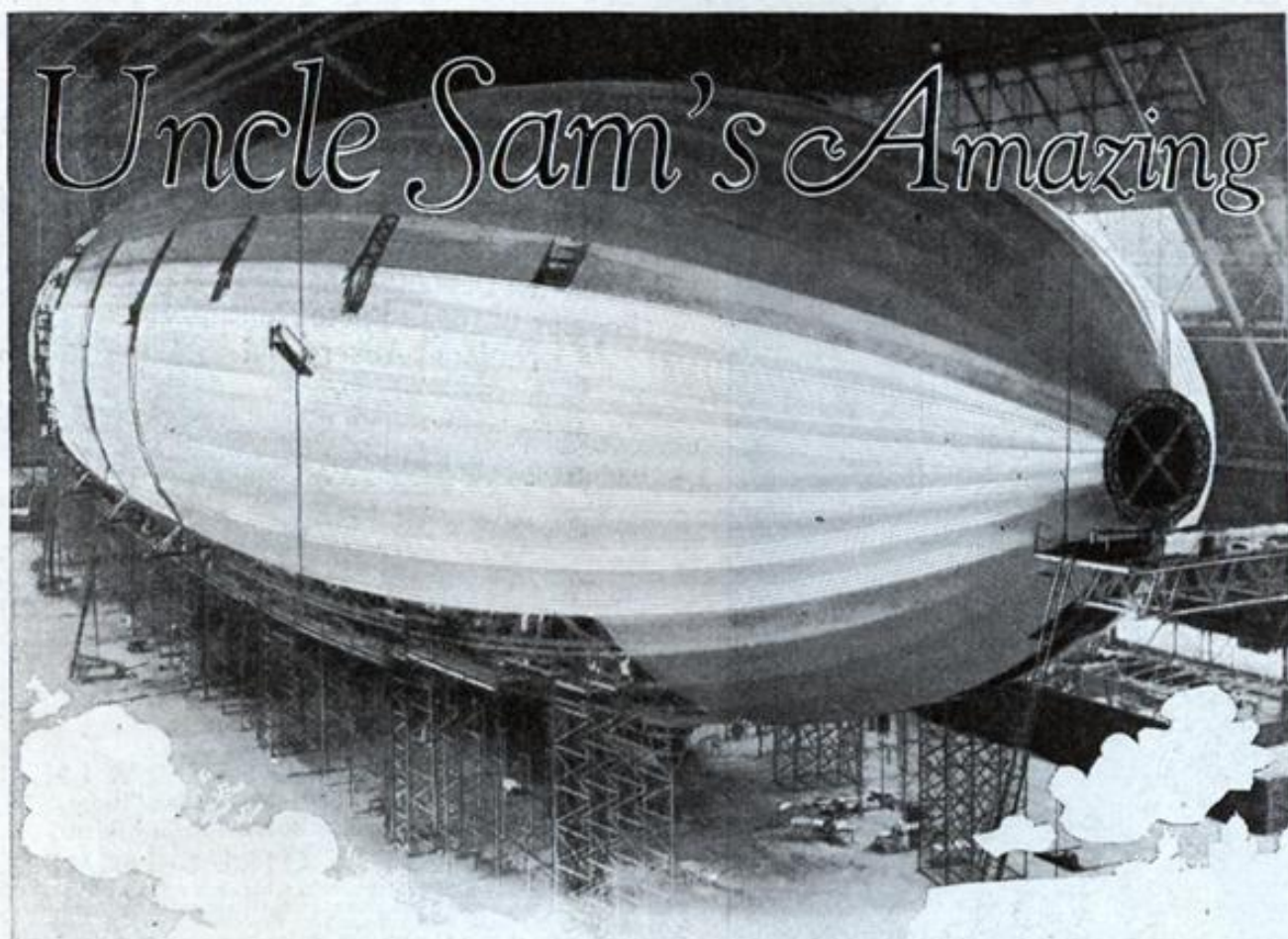
PLAN OF SUGGESTED SUPER-
SONIC LINER WITH A TOTAL
WEIGHT OF 100,000 POUNDS



SIDE VIEW OF SUGGESTED LINER ON THE "SWALLOW"
PLAN FOR SOME 60 REAR-FACING PASSENGERS

THIS IS A PHOTOGRAPH OF A MODEL OF THE
"SWALLOW" SHOWING THE WINGS IN VARIOUS
POSITIONS DURING ALTERING ASPECTS FOR
TAKEOFF AND LANDING, AND SUPERSONIC FLIGHT





In covering the framework of the Akron, linen airplane fabric is used, coated with airplane dope.

by DR. KARL ARNSTEIN

(Vice President and Chief Engineer, Goodyear Zeppelin Corp.)

As told to JAY EARLE MILLER

The biggest airship in the world, an amazing structure which is veritably a flying battleship, is practically finished and ready for test flights by the U. S. Navy. The man who supervised the design of this warship of the sky reveals here the fascinating mechanical details of its construction.

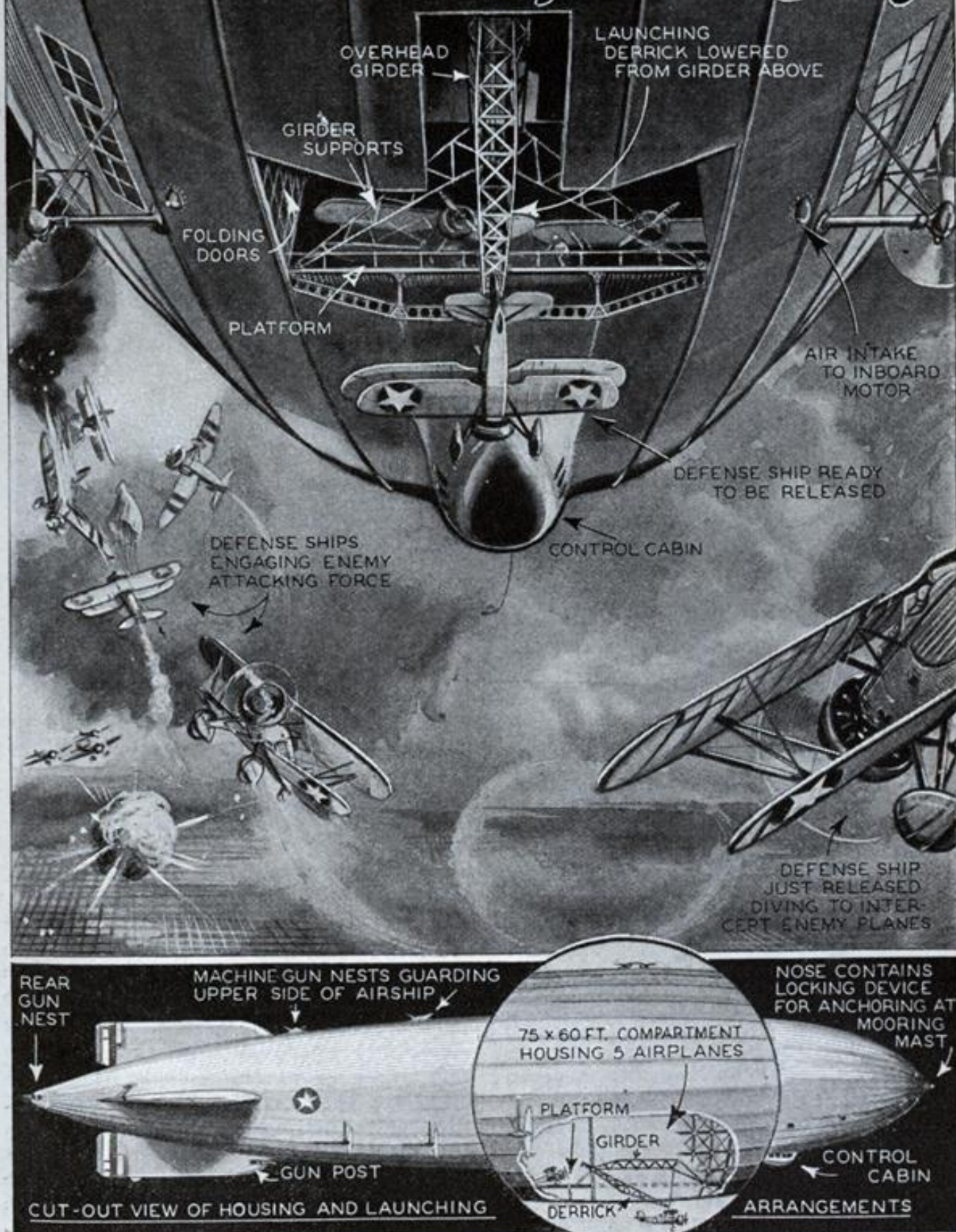
ABOUT the time this article appears in print the largest lighter-than-air ship ever built—the 6,500,000 cubic feet *Akron* will be walked out of the world's largest airship dock, or hangar, for its initial trial flight.

When the *Akron* takes to the air, the dream of Count Zeppelin—a super-airship capable of taking its place in world commerce—will have been realized. Not that the *Akron* is such a ship, for it is purely a military craft, a sort of flying battleship, built for scouting work with the fleet at sea, but it contains within it all the essentials which the coming trans-oceanic air liners will need, save actual passenger compartments.

It has the size and the power to ride out storms and maintain regular and fast service, the scientifically calculated strength to withstand extreme air conditions which may be encountered and the safety features only possible in American built ships inflated with American helium.

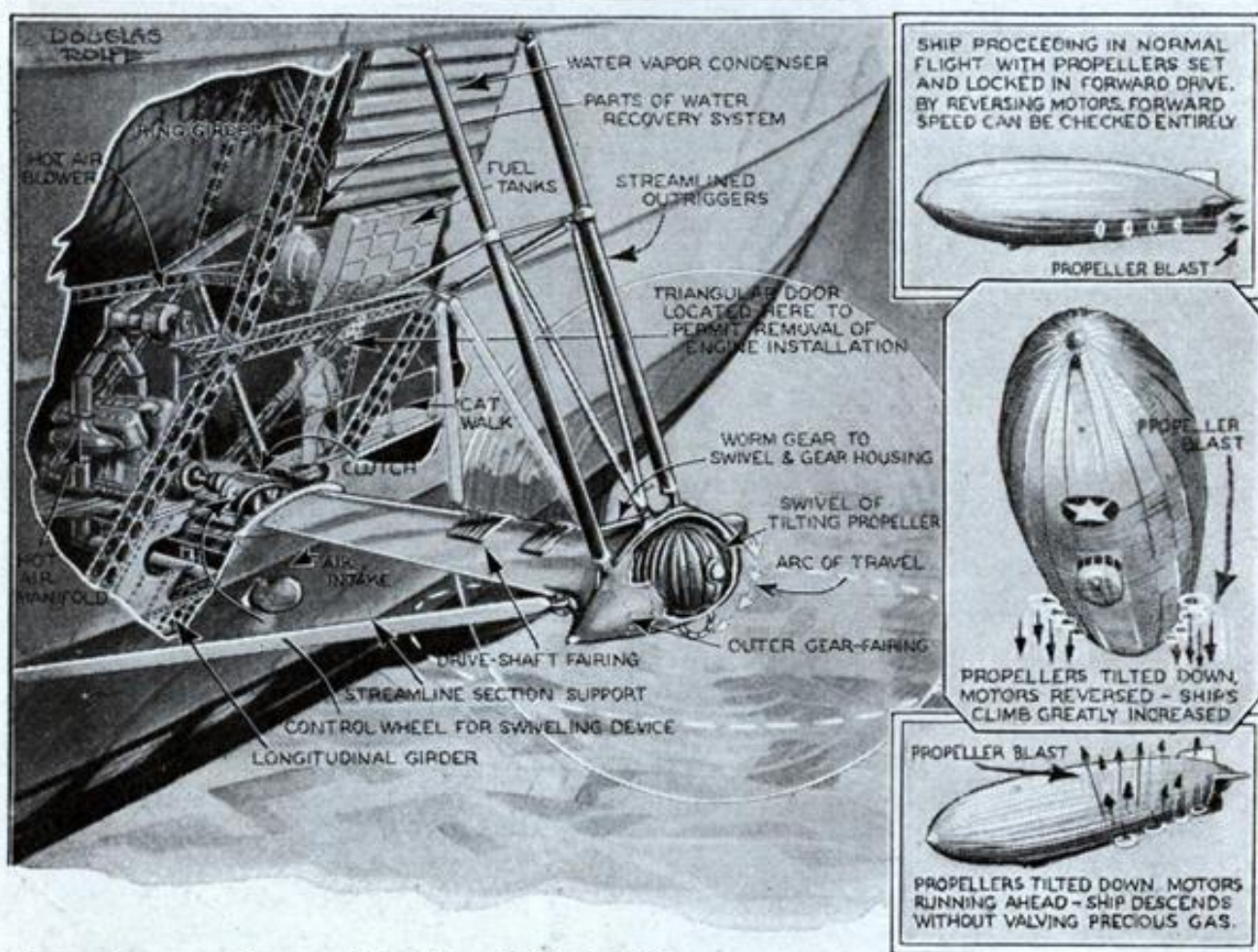
Aside from the new methods in construction, the outstanding feature of the *Akron* will be the hangar built within the hull to house five scouting and pursuit airplanes, both to supplement her scouting activities and to aid in her defense if attacked by enemy planes. A truss built between the main frames in the second bay aft of the control car is placed directly above a "T" shaped door opening in the bottom of the

WARSHIP of the Sky



Essential features of the airplane launching device and arrangement of defending guns of the Akron are pictured here. The airship is a self-sufficient flying unit with an unusually wide cruising range.

'Fat' Design of Akron Increases Gas Capacity, Gives Better Streamlining



A most important feature of the Akron is the installation of motors inside the bag, made possible by the use of non-explosive helium gas for inflation. Note the advantages gained through the use of swiveling propellers, which travel through 90 degrees of arc.

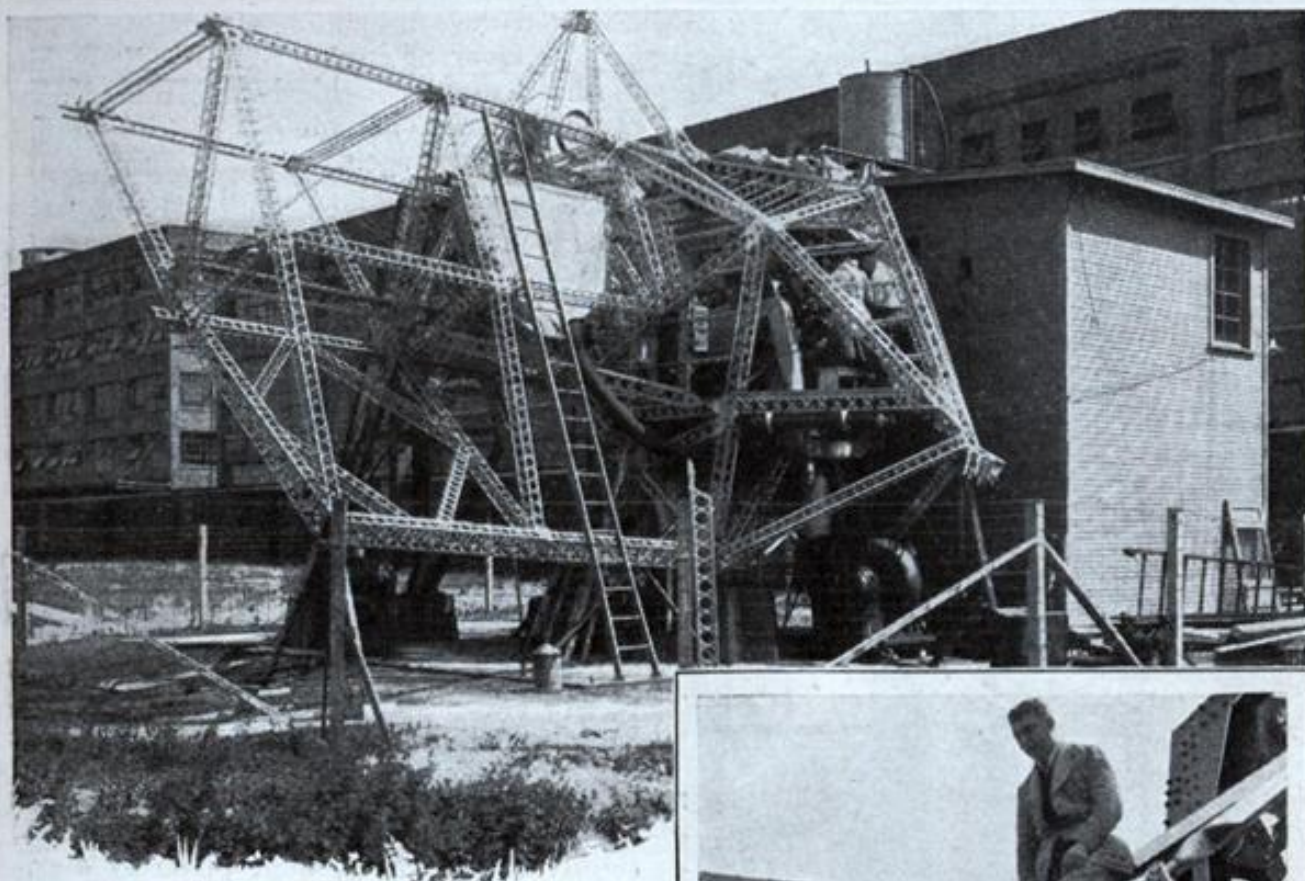
fabric covering. Through this opening a trapeze will be lowered, and the airplanes, with a hook above their upper wing, will fly up and make contact, as has been done many times in experiments with the *Los Angeles*. After they have attached themselves the planes will be drawn up within the hull and hung up in storage from the supporting truss. The airplane compartment, 75 feet long and 60 feet wide, will provide space for five airplanes.

Airplanes and armament are to be provided by the navy department, but the original plans called for gun nests in the nose and tail, on top of the hull above the control car, in either side amidships, and in the leading edge of both the vertical stabilizing fins, above and below the hull. The lower fin also is to contain an emergency steering station for use in event of the failure of the cables from the control car. Provision also is made for one or two basket cars, which may be lowered by cables from the ship, flying above the clouds, per-

mitting observers to be lowered below the clouds, from where they can direct operations by telephone.

The ZRS-4 (the official designation of the ship pending her launching and naming) is one of two sister ships ordered by the U. S. Navy department from the Goodyear-Zeppelin Corporation of Akron, Ohio, and the name selected for the first one built is a tribute to its birthplace. In size, which, in lighter-than-air ships means lifting gas capacity, the ZRS-4 and ZRS-5 will each be nearly twice as large as the *Graf Zeppelin* and considerably more than two and a half times as large as the Navy's *Los Angeles*. The latter has a gas capacity of 2,470,000 cubic feet, the *Graf Zeppelin* has 3,700,000, and the two American ships will each contain 6,500,000 cubic feet of lifting gas. They will be about 35% larger than the 5,000,000 cubic foot R-100 and R-101, built in England.

Despite the vast increase in size, the *Akron* is only 15 feet longer than the *Graf*



To test the efficiency of the swiveling propeller, a section of the Akron's framework was erected outdoors as shown above and the motor run for 50 hours to make sure there were no "bugs."

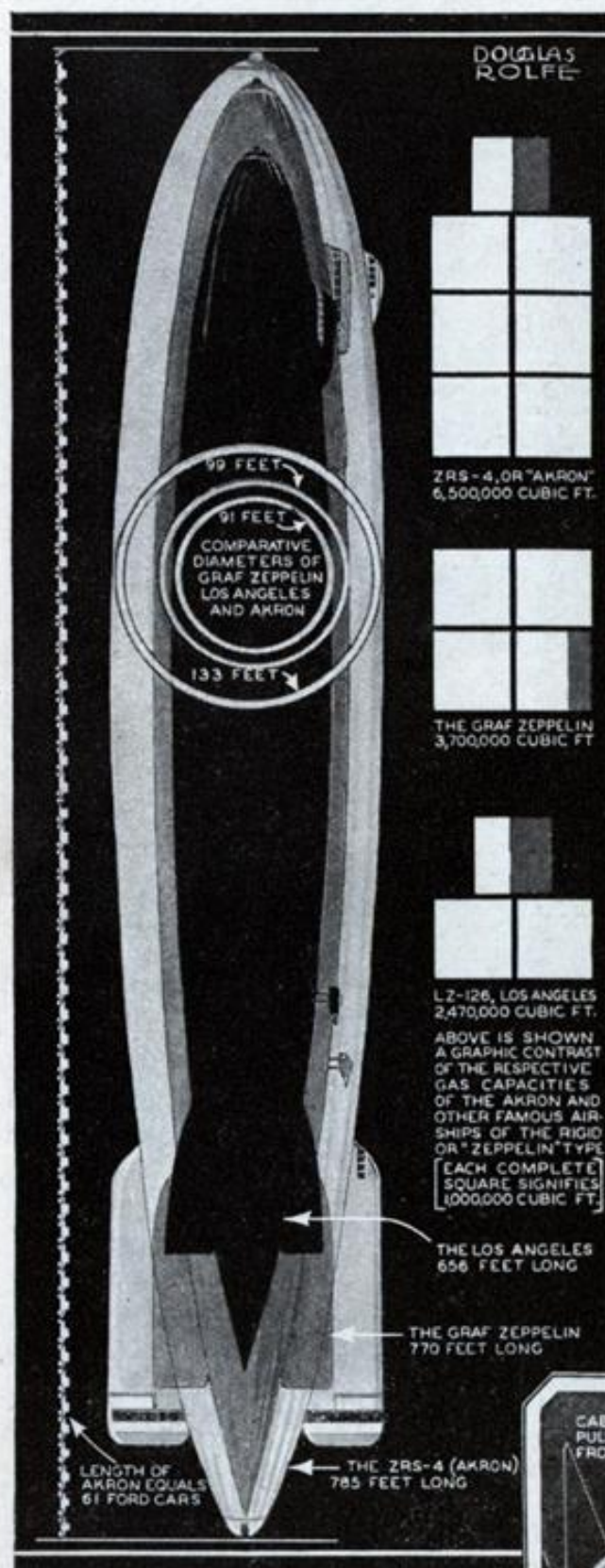
Zeppelin, but 34 feet greater in diameter. Those dimensions, 785 feet long by 132.9 feet in diameter, makes the *Akron* a fatter, more rounded ship, a contour that has marked advantages. The slim lines of the *Graf*, the *Los Angeles* and the German war-time *Zeppelins*, were not dictated by aerodynamical considerations so much as by limited hangar space in which to build them, and, in the case of the "lead pencil" shaped war-time ships, considerations of quantity production. Volume for volume the surface of a fatter ship offers less frictional resistance to the air, but the greater diameter causes an increased form drag. Tests have shown that the advantages of fatness reach their height in comparison to the disadvantages of form resistance when the length is somewhere between five to seven and a half times the diameter, so the fineness ratio of the ZRS-4 of 5.9 comes well within those limits, and is much superior to the 7.7 ratio of the *Graf Zeppelin*.

The outstanding features of the American ships, however, is a vastly improved



Inside the sphere at the base of the propeller shaft are housed the bevel gears which are the heart of the swiveling device.

Ability of Propellers to Swivel in Ninety-Degree Arc Is Novel Feature



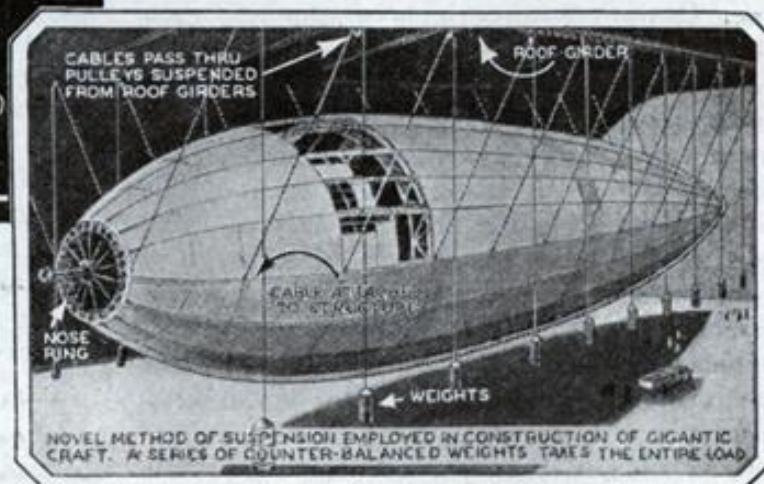
Graphic comparison of the Akron with the Los Angeles and Graf Zeppelin reveals striking differences in size and proportion. Although the Graf Zeppelin is practically the same length as the Akron, it has slightly more than half the gas capacity. At right is shown the method of suspending the Akron from the hangar roof by counterbalanced weights.

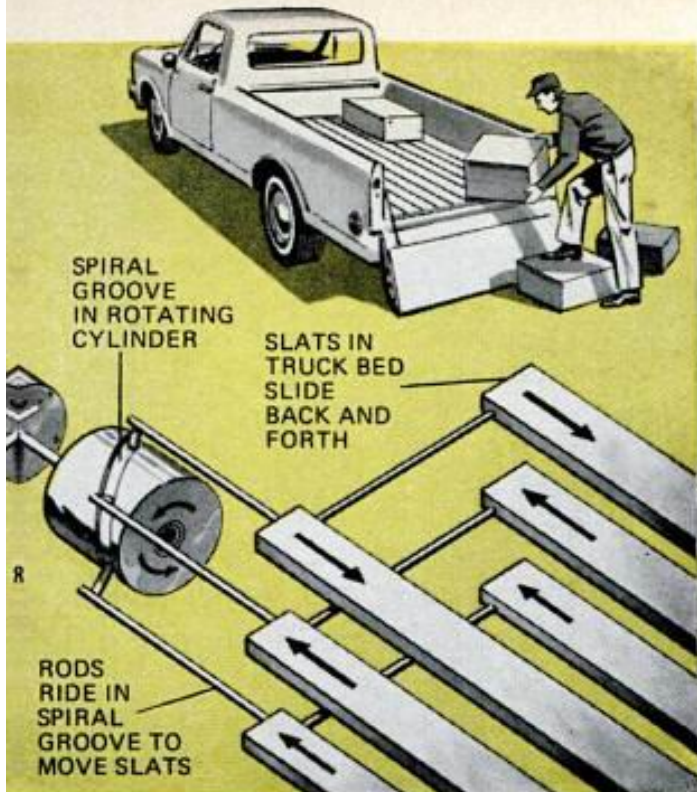
form of construction made possible by their size, and the elimination of exterior power cars in favor of engine rooms built within the hull, made possible by the use of non-explosive, inert helium gas instead of the dangerous hydrogen.

To understand how we have improved the form of construction it is necessary to consider the evolution of the Zeppelin design. Airships built to Count Zeppelin's triple layer principle—which means a series of separate gas cells, a rigid framework to confine them and support the load, and an outer covering to protect the other members against the weather and furnish a smooth flying surface—fall naturally into three classes, which might be called small, medium, and large ships.

The *Bodensee*, built at Friedrichshafen in 1919 for passenger purposes, is typical of the smaller class, the *Los Angeles*, built in Germany for the U. S. Navy of the medium type, and the new naval ships are of the larger type. In the smaller class the hull is a series of main transverse girders, rigidly braced within their plane by a system of cross wires, holding together all the corners. One of these main girders or rings is placed between each pair of gas cells, and they are joined by longitudinal rib girders, which in turn are strengthened by intermediate rings between the main girders. In the *Bodensee* the main rings were seventeen-sided polygons, with from three to four bracing wires extending from each of the corners where two sides were joined. One of the seventeen sides was placed horizontally at the bottom to form the floor of the corridor.

In the *Los Angeles* the main frames were 22-sided polygons, developed from regular





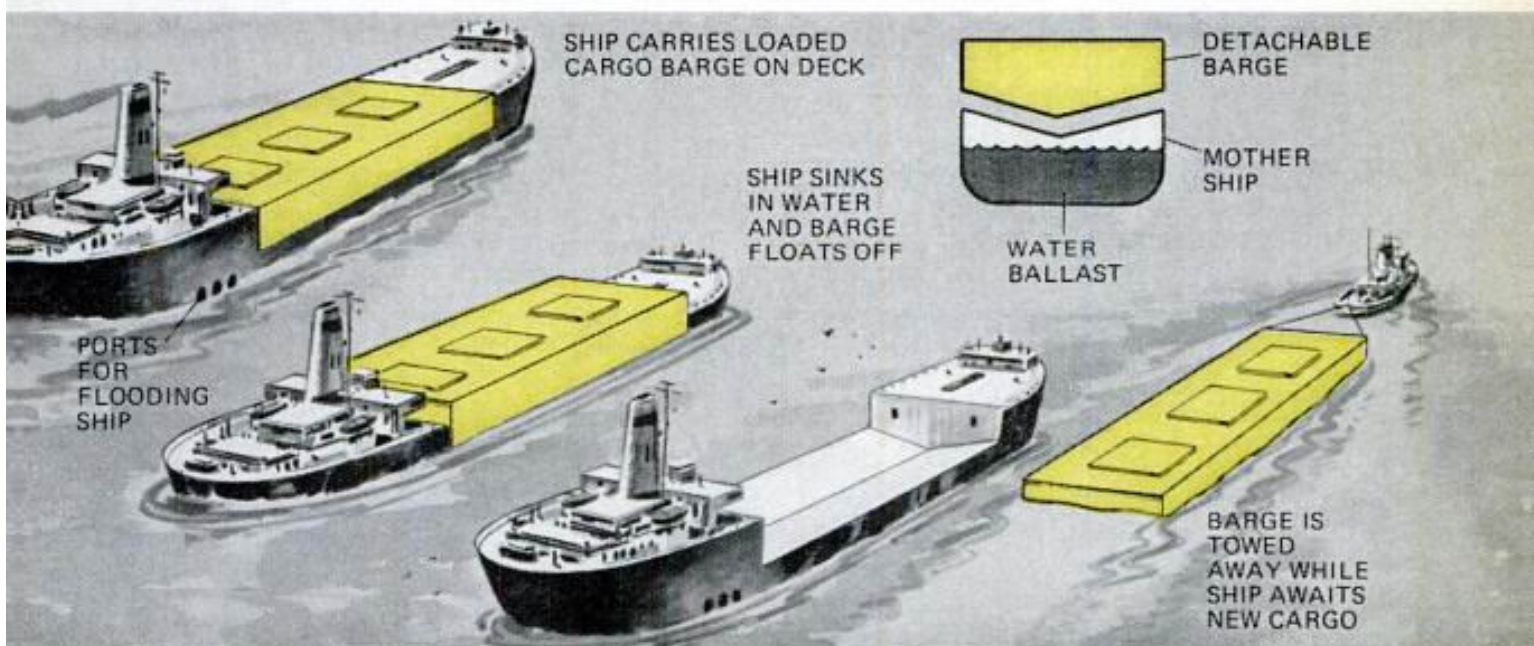
3. SELF-LOADING PICKUP TRUCK fills itself as you put cargo in at the rear. Its moving floor consists of slats driven back and forth by rods riding in a spiral-grooved drum. The slats are arranged in sets of three so that two are always moving forward while the third returns to the rear. This produces a conveyor-like action that draws cargo into the truck. For quick unloading, the slats are reversed



4. WALKING ON STEEP SURFACES would be a cinch with these strap-on "roof shoes" to keep your feet level. Designed for roofers, painters and TV installers, the angled supports can be adjusted to suit different roof slopes and have foam rubber pads on the bottom to prevent slipping, even on wet surfaces. The pivoted foot plates can be quickly reversed to permit walking either up or down a roof

5. UNLOADING CARGO from this novel freighter is simple—you just sink the ship out from under it. The cargo-carrying section is designed as a separate, removable barge. When the ship reaches port, water ballast compartments are flooded, lowering the hull beneath the barge. The barge floats off free and

is picked up by a tugboat for delivery to points along inland waterways. The system saves unloading time and speeds the shipment of cargoes to inland ports. The barge's V-shaped bottom locks into a similarly V-shaped recess that's cut into the ship's hull to hold it securely in place during the voyage



Inventors of the items shown on these pages are as follows: 1. Fred R. Nebiker, Akron, Ohio (No. 3,508,725); 2. Fu-Shueng Chang, Melvindale, Mich. (No. 3,508,785);

3. Olof A. Hallstrom Jr., Tillamook, Ore. (No. 3,534,875); 4. Herbert Stokes, Abergele, North Wales; 5. Arthur William Vienna, Encino, Calif. (No. 3,508,514).

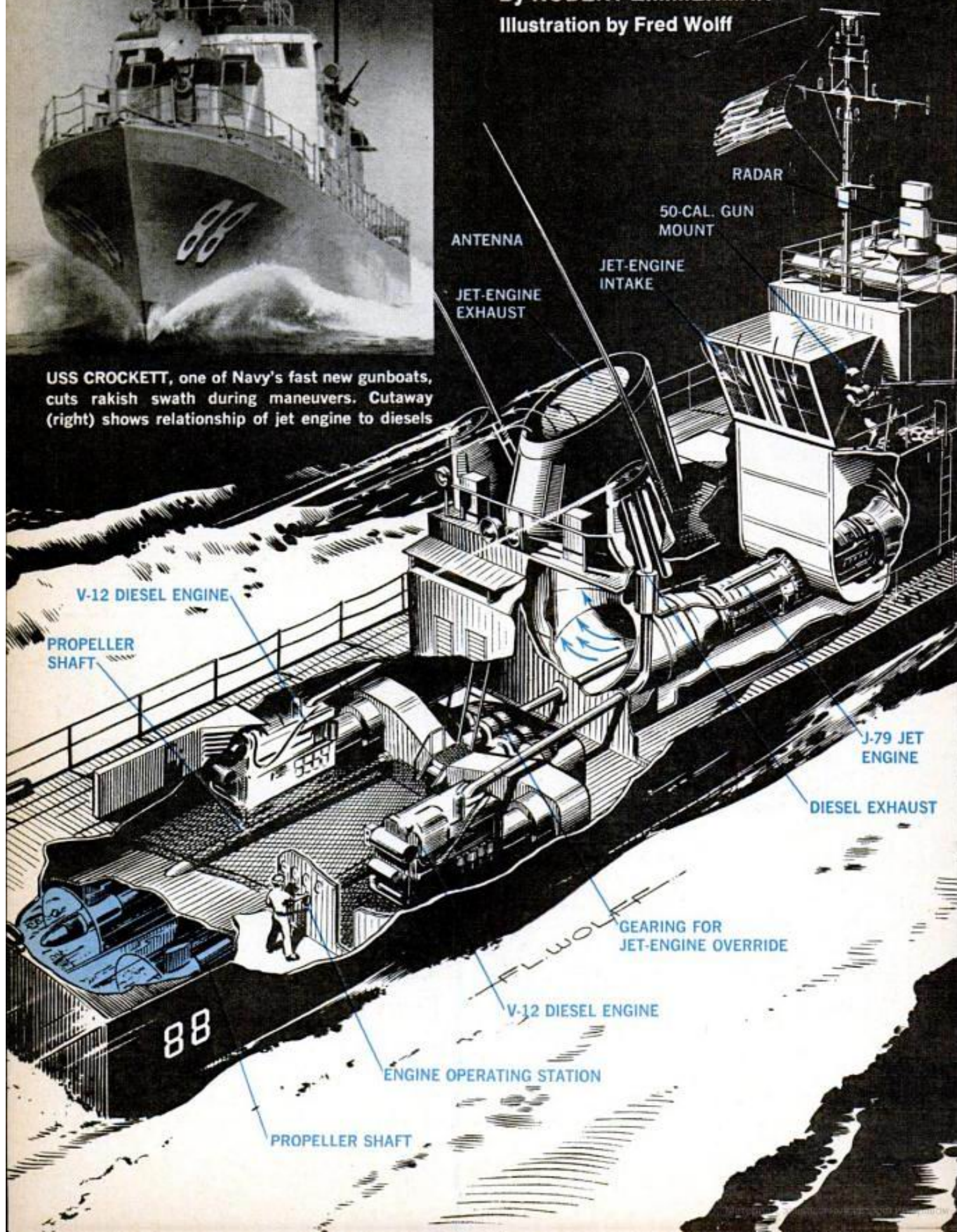
From a Dead

By ROBERT ZIMMERMAN

Illustration by Fred Wolff



USS CROCKETT, one of Navy's fast new gunboats, cuts rakish swath during maneuvers. Cutaway (right) shows relationship of jet engine to diesels



Stop to 40 Knots In 75 Seconds

PILOTHOUSE

3-IN. GUN TURRET



The Navy's new, hard-hitting patrol gunboat is a 165-foot aluminum-hulled speedster that can switch from diesel to jet power—and the crew needs seat belts.

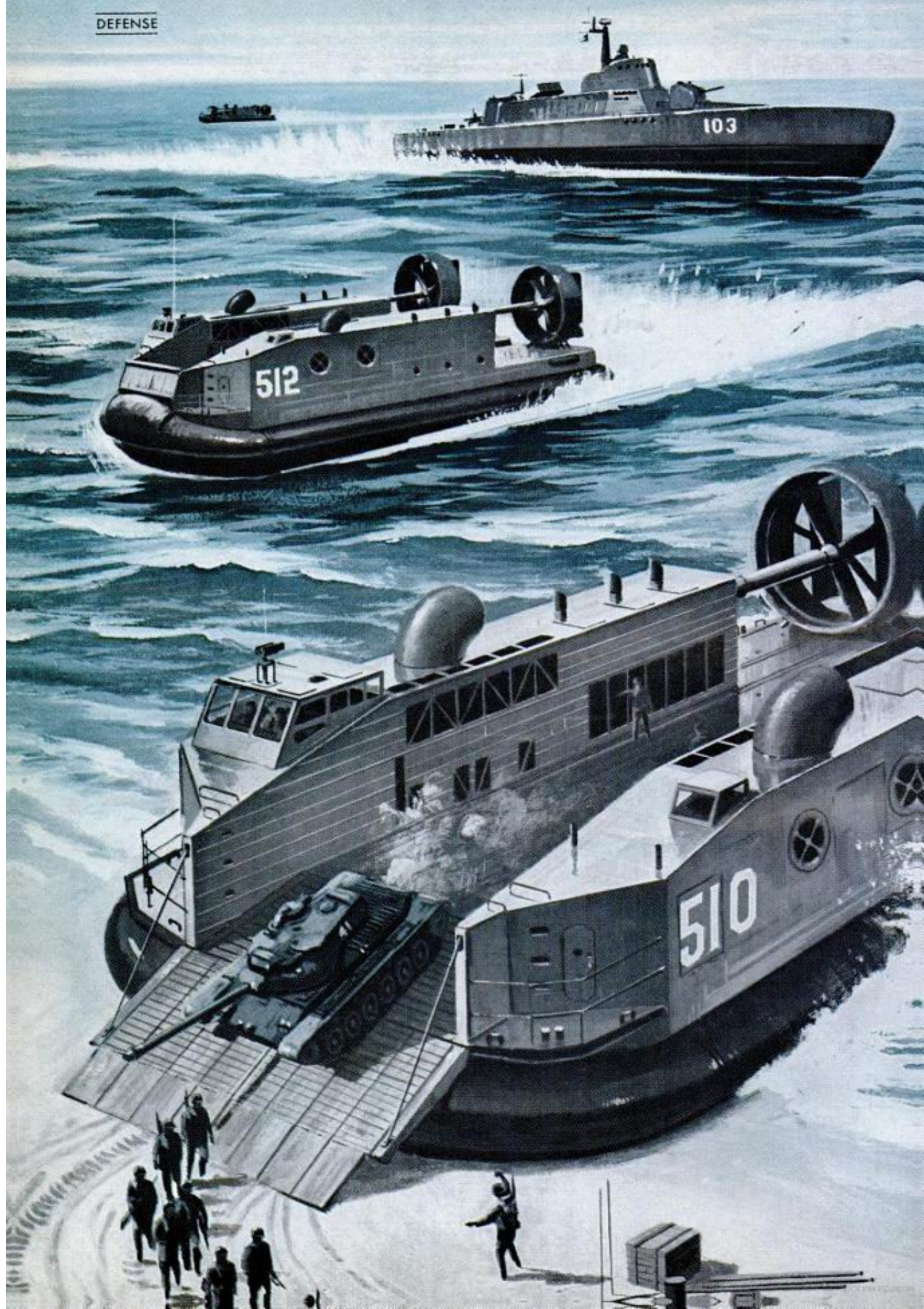
THE NAVY GUNBOAT USS *Gallup* had been plowing through the swells at 15 knots, no strain for her two 725-hp diesel engines. Then the helmsman pushed forward on a throttle marked "Turbine," and the sailor standing next to me on the bridge said, "Hang on."

I hung on and I'm glad I did. A sudden burst of power pitched up the bow of the 165-foot aluminum-hulled *Gallup* and we were off and running. The needle on the speed indicator began moving like the sweep hand on a watch—20 knots . . . 30 . . . 35 . . . 40!

That high-pitched whine mounting in our ears was a J-79 turbojet engine, the same kind that powers an F-4 Phantom II fighter. Only this one was pouring 14,000 horsepower into the *Gallup's* twin screws.

Lt. Cmdr. Bill Spane, the skipper, took over the helm, a swivel stool in front of a 10-inch steering wheel. He put the *Gallup* through flank-speed maneuvers that had us rolling into our spray. It was easy to see why the designers had called for anchored seats at each duty station throughout this revolutionary new warship—and why they added seat belts for good measure.

Spane sent a man scurrying to the top deck to haul down the colors. "Usually





A fast fleet that rides on **AIR**

Warfare on the high seas will never be the same if Navy's revolutionary plan to launch 100-knot ships is successful

By MORT SCHULTZ

TO MEET the seagoing challenges of the 1980s, the Navy is developing an armada of small vessels able to ride on a cushion of air while doing 100 knots—a speed conventional ships can never hope to equal.

The Navy calls them surface-effect ships (SES), and foresees the day when they will swiftly hunt down and destroy nuclear submarines, act as fast-moving missile launching platforms, or safely haul cargo and troops from a mother ship to an inland point after hopping over the beach.

In asking for \$40-million this fiscal year to push the SES project, Rear Adm. William H. Livingston, director of the Navy's Air, Surface and Electronics Warfare Div., told Congress that "almost all Navy missions can be

enhanced by surface-effect ships. They can go faster."

Conventional ships waste a large portion of their power simply pushing water out of the way, particularly at high speeds. A streamlined destroyer, for example, can make 27 knots with 15,000 hp. Doubling the horsepower doesn't help that much; the ship reaches only 32 knots.

SESSs, however, use the additional power to rise above the water, reducing or eliminating hull drag while substantially improving their speed.

Right now, the Navy brass is keeping an eye on two SES types being developed by Bell Aerospace Co. and Aerojet-General Corp. One craft "flies" over the water on a cushion of air. The other uses an air bubble to lift the front of the hull above the waves, leaving two thin sidewalls in the aft section extending several feet below the waterline to add stability and prevent skidding during turns.

The two aerospace outfits are building slightly different 100-ton prototypes of the air-bubble vessel—scale models of transoceanic ships weighing 4000 to 5000 tons, the approximate size of a destroyer escort.

Bell's version, SES-100B, a 77-foot-long, 35-foot-wide aluminum craft, rides on a cushion of air trapped by catamaran-style side hulls and flexible nylon-rubber bow and stern seals. The air is generated by eight lift fans driven by three 500-hp ST6J-70 marine gas turbine engines made by United Aircraft of Canada.

When cruising, the bow and center portion of the hull clears the water,



HULL STRUCTURE of Bell Aerospace's 100-ton prototype surface-effect ship is completely aluminum

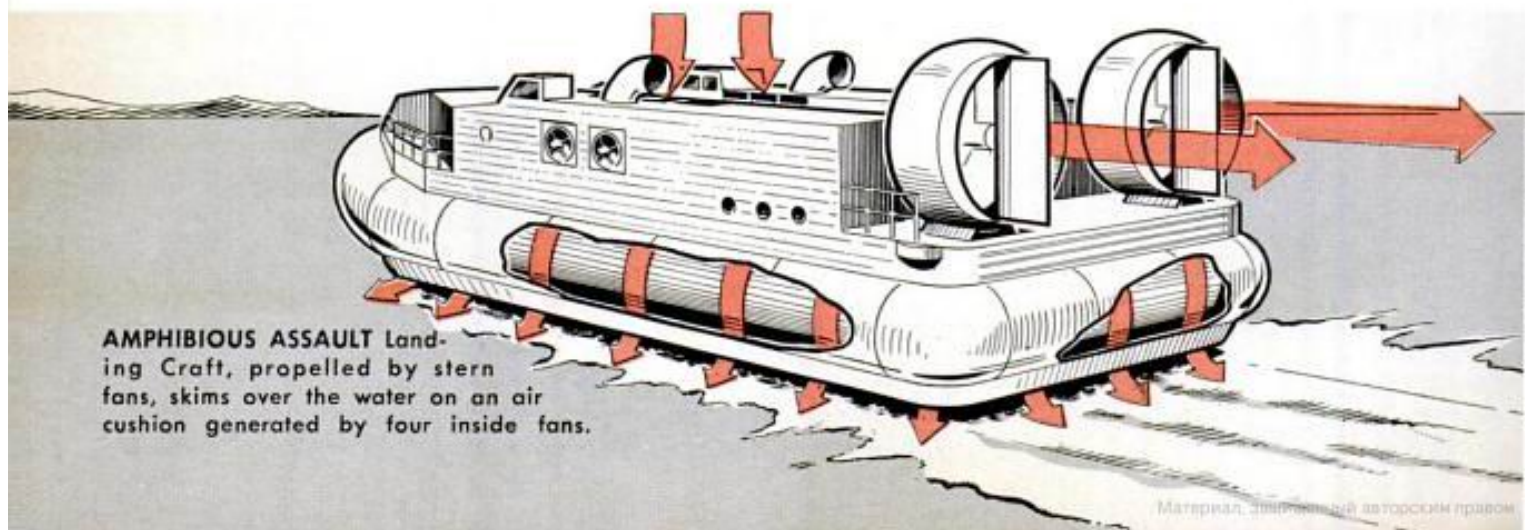
entirely supported by the trapped air bubble.

Propulsion comes from three Pratt & Whitney 4500-hp FT12A-6 marine gas turbines that drive two semisubmerged, controllable-pitch, supercavitating propellers in the stern.

Trial runs of the Bell midget carrying a crew of four, six observers and a 10-ton payload are being held this year in the Gulf of Mexico to determine if the craft can be routinely pushed to 80 knots. If that speed is easily reached, engineers will try for 100 knots.

Aerojet-General's pioneer will be slightly longer than the Bell version—80.5 feet long, and 38 feet wide—but more significant is the difference in propulsion. Instead of semisubmerged props, the Aerojet-General SES-100A has a propulsion system that uses two powerful water-jet pumps. Both pumps and the three lift fans get their juice from four 3500-hp gas turbines.

If the SES prototypes prove them-



AMPHIBIOUS ASSAULT Landing Craft, propelled by stern fans, skims over the water on an air cushion generated by four inside fans.



LANDING CRAFT (shown in a full-scale mock-up) designed to carry a 60-ton tank plus fighting men

selves, it's likely the first application will be SES antisubmarine vessels. A full-grown 100-knot SES would be much faster than the nuclear submarines that now outrun today's 40-knot subchasers, and would be able to twist and turn tightly, thanks to their underwater sea legs. They'd also be less vulnerable to enemy sub sonar and wouldn't present much of a torpedo target because only a small portion of their hull is in the sea.

In the rush to develop 100-knot SESs, the Navy hasn't forgotten a primary mission—landing troops and their back-up cargo on an invasion beach. Bell and Aerojet-General have contracts to work out two amphibious assault landing craft, nicknamed JEFFs.

The boats, designated C150-50, are based on the Navy's combat experience in Vietnam in 1966 and 1967 when 10 air-cushion patrol vehicles were tried out (see *'Tiger Sharks' strike in the Vietnam swamps*, page 131, Nov. '67 PM). Called hovercraft, the vessels

were awkward-looking, small pancakes 39 feet long, 24 feet wide, and powered by a single 1150-hp General Electric gas turbine that sent them skimming four feet above the Delta at 60 knots.

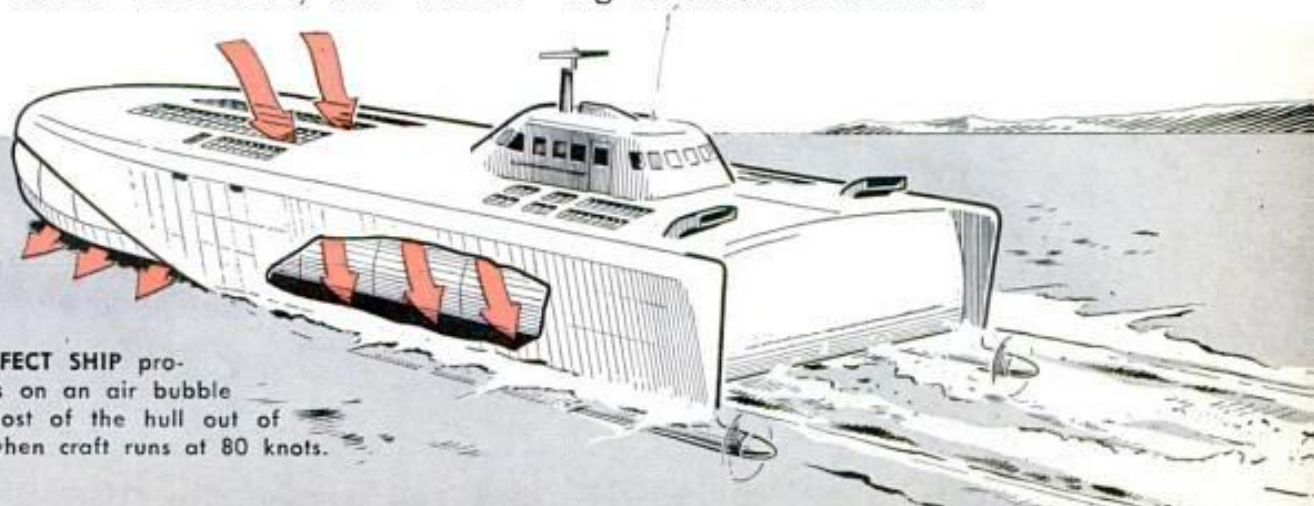
Today's JEFF has come a long way from those early experiments. Bell's prototype calls for a craft 90 feet long and 47 feet wide, able to carry 75 tons of cargo above the water or beach while riding completely on a cushion of air. Top speed: 50 knots, or five times faster than the assault boats that hit the beach at Normandy.

Six 2800-hp marine gas turbines will drive a pair of 14-foot diameter propellers mounted above the stern to push the boat while four five-foot fans on the sides maintain the air cushion.

The Navy will run boats from mother ships able to stand 200 miles off the invasion beach, safely out of range of crippling shore batteries. While JEFFs won't be as fast as the early hovercraft, they'll carry much more cargo—vital when supporting an invasion.

These SES projects make up the giant portion of the Navy's small ship program. Other projects include a \$12.9-million program for hydrofoil experiments plus \$3-million for work on "sea control" ships—small seagoing platforms able to launch helicopters and short takeoff jet attack aircraft.

But the lion's share is going to SES projects. Reason: A report to the Pentagon by the Institute of Defense Analysis concluded that "the principle of air-cushion vehicles appears to offer more potential for naval military surface vehicles than any other development during the last two centuries." ★ ★ ★



SURFACE-EFFECT SHIP prototype rides on an air bubble that lifts most of the hull out of the water when craft runs at 80 knots.



Disney Builds the Clean,

THE CURTAIN GOES UP this month on today's greatest show on Earth—Walt Disney World, a \$300-million, 43-square-mile vacationland near Orlando, Fla. At its center is a fancier, larger version of California's famed Disneyland.

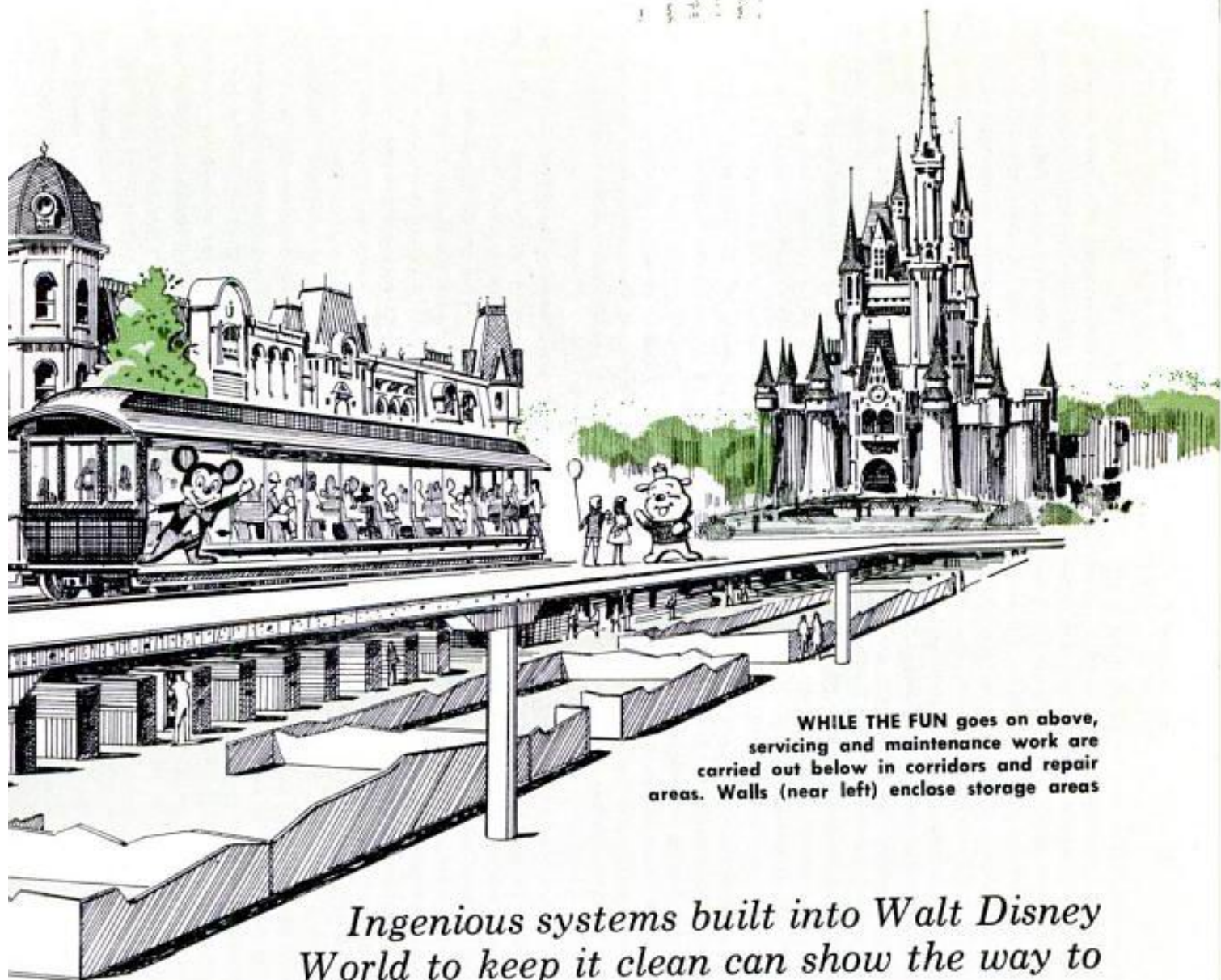
But Disney World has more to offer than entertainment. It's designed to be a preview of the kind of America we can have tomorrow. Here the air and water will be pure, much of the wilderness will remain untouched, and man will be master—not victim—of the machine.

With 10 million people visiting the park each year, its example soon should have an impact on citizens in every part of America, including city planners, politicians, housewives, automakers and industrial polluters.

Here, in a "town" that will host 35,000 people, will be nuts-and-bolts proof that good design can preserve the best of nature without being more expensive. Here, as well, will be machinery, materials and systems to make life in the future pleasanter and safer. Even bigger innovations are in the offing.

To see it all, you must first park your

POPULAR MECHANICS



WHILE THE FUN goes on above, servicing and maintenance work are carried out below in corridors and repair areas. Walls (near left) enclose storage areas

Ingenious systems built into Walt Disney World to keep it clean can show the way to pollution-free cities of the future. By ELLIOTT H. McCLEARY

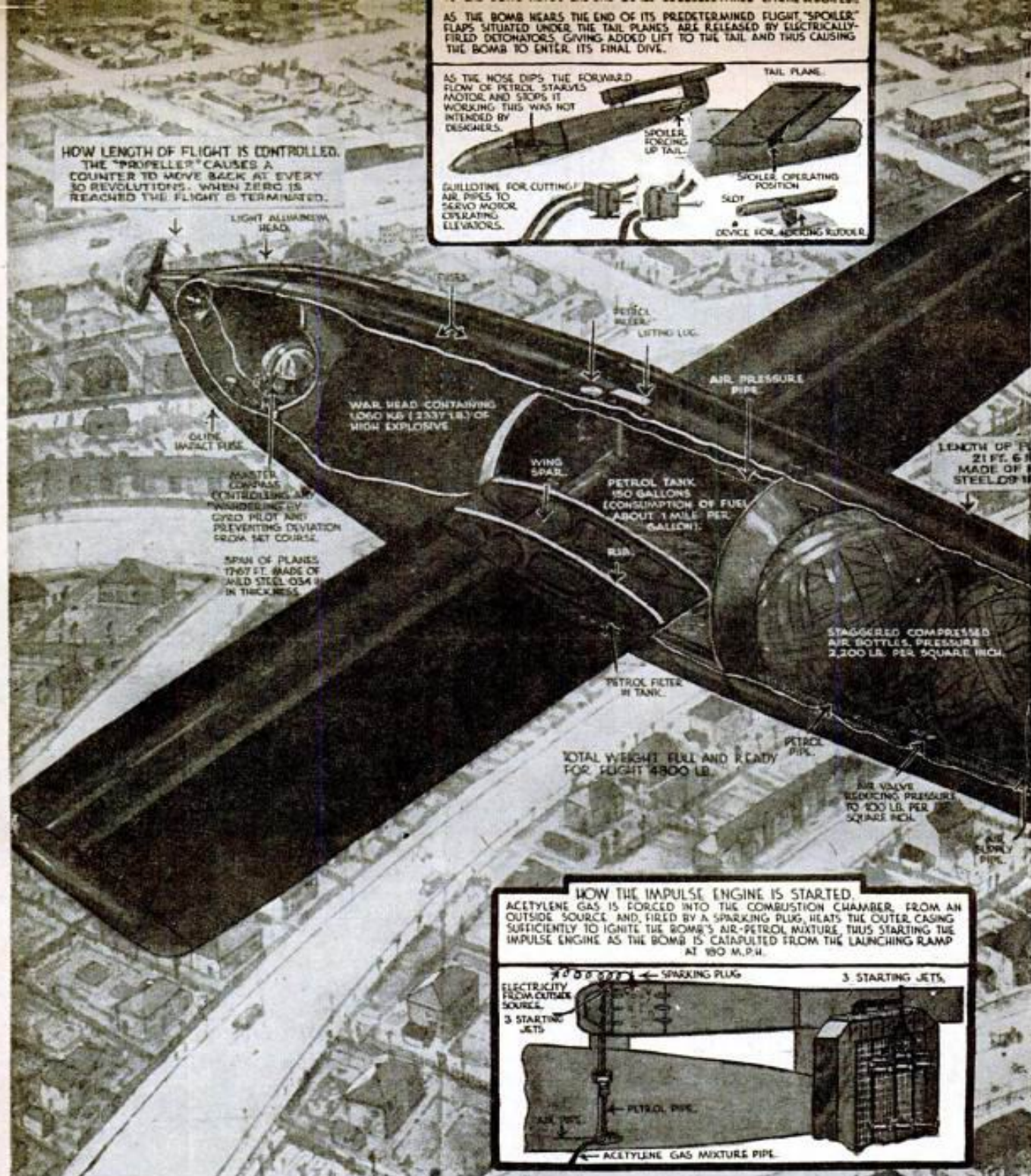
Green World of Tomorrow

"smog generator" in a 12,000-car lot more than a mile from the 100-acre family entertainment park. In Walt Disney World the automobile is kept on the fringes, barely tolerated.

You are taken in a tram to a loading area where you can board an electric monorail train or one of a fleet of watercraft—replicas of old-time steamers—that ply a manmade lagoon. Like virtually all the boats and nonelectric vehicles in the park, the tram is powered by clean natural gas compressed on the premises for engine fuel.

Smoothly and quietly the monorail





SECRETS OF THE V-1 FLYING BOMB. This drawing by G. H. Davis for the Illustrated London News shows what the British have learned about the robomb from careful examination of specimens shot down or found unexploded. V-1 is, in effect, a small, automatically controlled, jet-propelled airplane carrying a ton of high explosive in its nose. Designed for quantity production, it is made almost entirely of

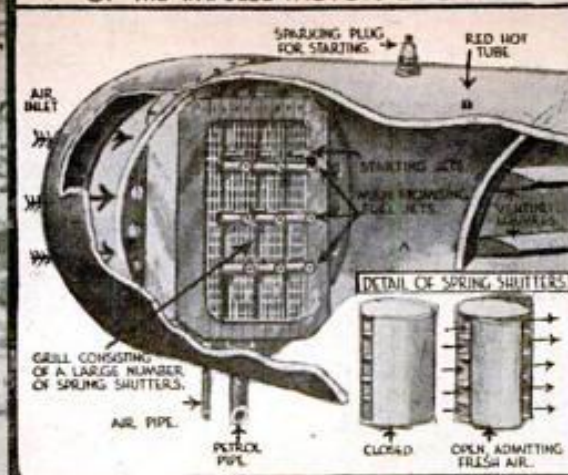
to dislodge great amounts of other solid materials. But the blast effects from their war heads was terrific.

The war heads of the V-2 bombs were similar, but these bombs penetrated more deeply than the V-1's. The result, Prime Minister Churchill has revealed, was "somewhat heavy damage in the immediate vicinity above the crater, with rather less extensive blast effect around it."

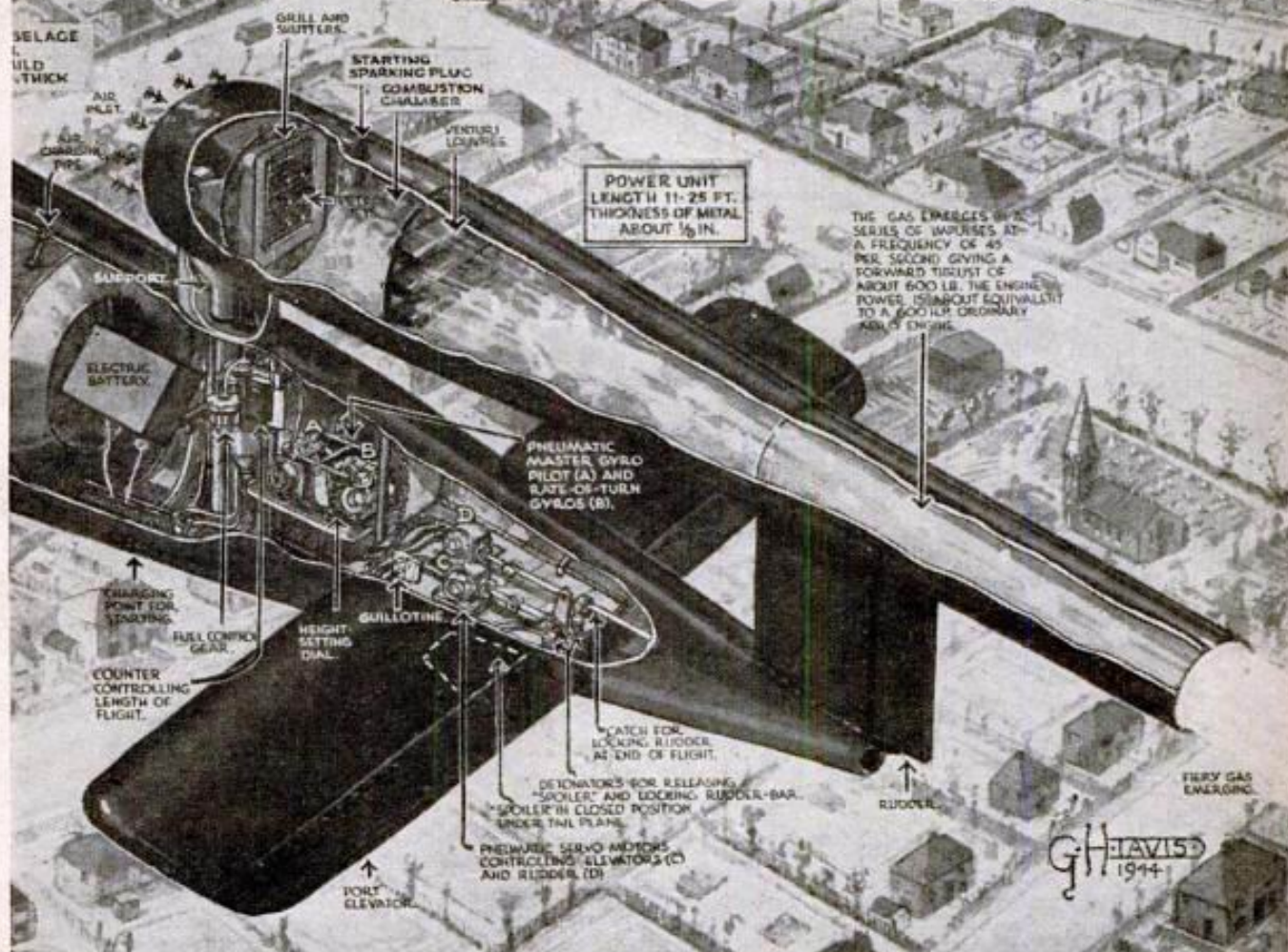
Blast effect consists of a sudden wave of pressure, quickly followed by a suction wave. The pressure wave is caused by the quick liberation and expansion of immense quantities of hot gases. The suction wave results largely from the cooling of these gases as they encounter resistance and lose momentum.

The detonation of a high explosive creates such intense heat that the temperature of

THE WORKING OF THE IMPULSE MOTOR EXPLAINED



WHEN the pressure in the combustion chamber ("A") is low, the shutters are forced open by outer air-pressure caused by speed, and a new charge of fresh air passes into the combustion chamber. At the same time, petrol is sprayed out of the atomising jets, the red-hot outer tube ("B") fires the petrol-air mixture, and combustion proceeds. As the compression in the combustion chamber rises, it forces the shutters to close and also momentarily cuts off the fuel supply. The only outlet then being the rear end of the tube, the escaping gases provide reaction to drive the bomb forward. The rapid progress of the hot gases down the tube leaves behind a partial vacuum, so that a wave of low pressure follows, allowing the shutters to reopen and draw in a fresh supply of air, thus repeating the cycle.



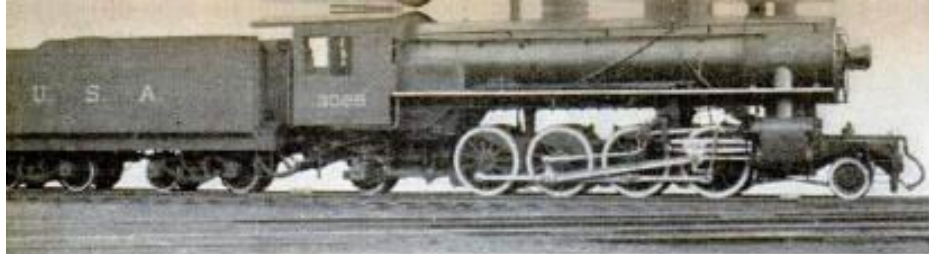
mild steel. Its pilot is a freely pivoted gyroscope driven by compressed air from spherical bottles. This is preset for direction and height of travel and corrects any deviation from course by operating the rudder and elevators through two servo motors. Distance is controlled by the "propeller" in the nose. When this has ticked off a predetermined number of revolutions, spoilers turn the bomb's nose downward

the gases freed is raised several thousand degrees. These gases burst out in all directions, much faster than sound travels. Part of their momentum is transmitted to the air, water, earth, or whatever else may surround them. Thus the expanding gases create an ultra-fierce hurricane which demolishes everything in its path until its force is spent.

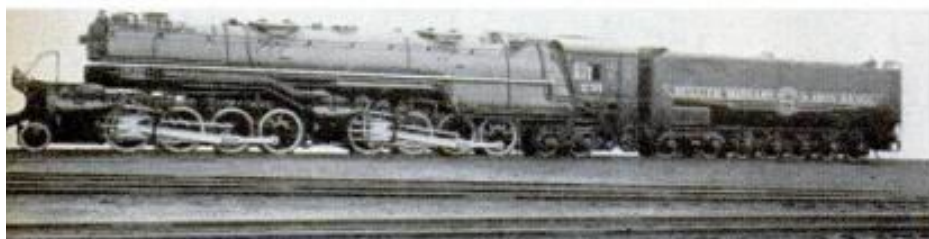
The stampede of gases and air leaves a

partial vacuum where the explosion occurred. Air rushes in to fill it, causing a slower but more prolonged wave of pressure toward rather than away from the site of the explosion.

According to an expert on the staff of the Research and Experiments Department of the British Ministry of Home Security, the initial outward pressure from the explosion of a V-1 robomb caused the *most serious*



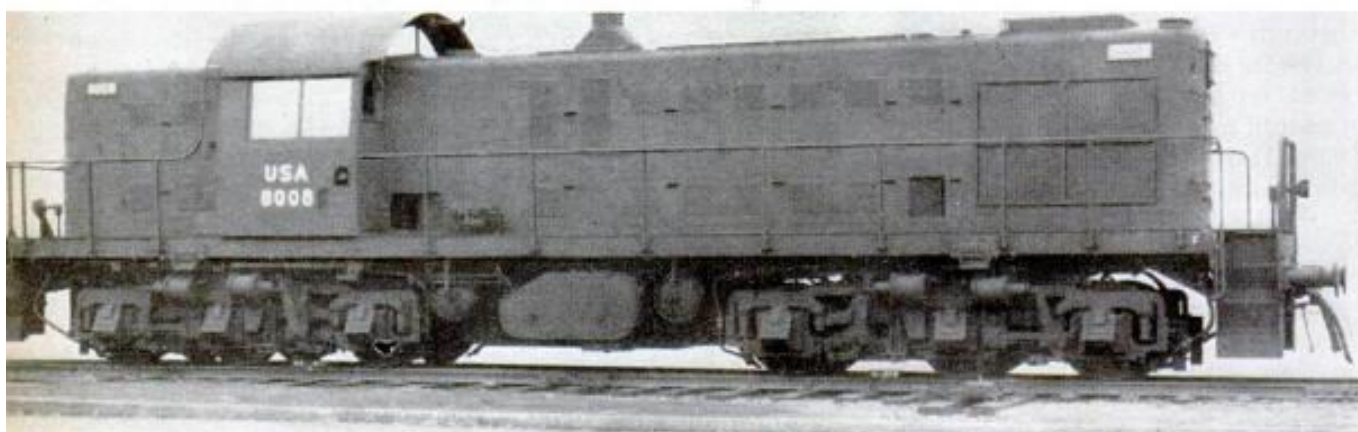
2-8-2. A variation on the 2-8-0, built by the American Locomotive Co. for the War Department, is this engine, which has a rear truck under its cab



2-8-8-4. One of the world's most powerful freight locomotives is the 2-8-8-4 (16 driving wheels), constructed for the job of hauling great loads of iron ore from the mines of Northern Minnesota to ports on Lake Superior

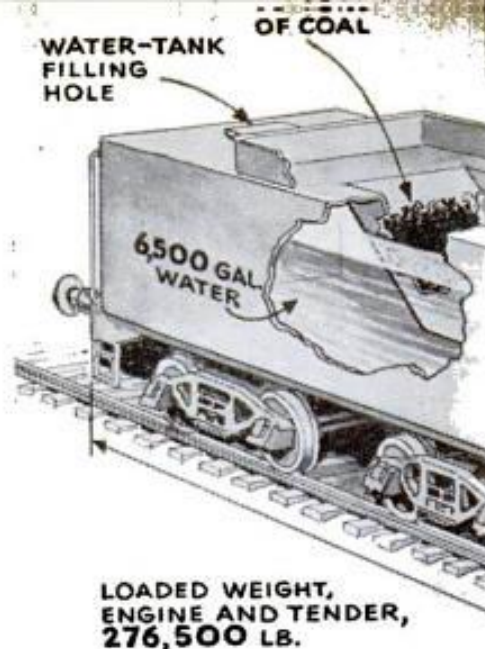


4-8-8-2. Another 16-driver locomotive, built by Baldwin, is the 4-8-8-2. The "4" in this instance stands for the number of wheels under the cab, as the 657,900-pound giant travels stern first to give clear visibility and freedom from gases in tunnels and snowsheds on the Southern Pacific

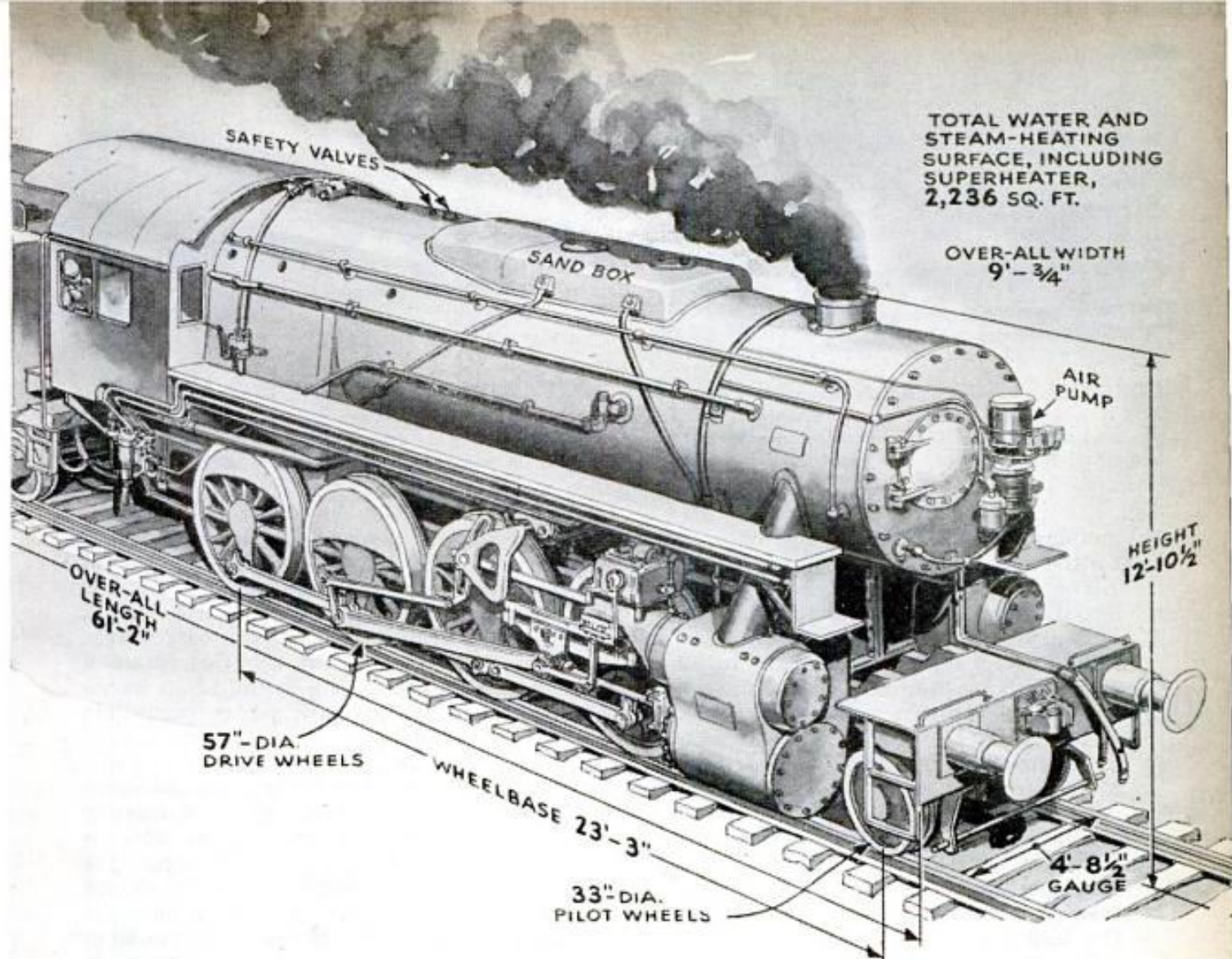


1,000-HP. DIESEL. This engine was especially designed with 12 driving wheels instead of the usual eight, so as to distribute its 254,000 pounds more evenly on the rails of distant Iran. The roadbeds on "the Shah's toy," as the 1,500-mile-long line is called, weren't built to take a heavier load per wheel

4-4-4-4. Each of the eight drivers of this ultramodern Pennsylvania steam locomotive, driven by tandem-set cylinders, bears a load of more than 32 tons, accounting for its tractive force, or pulling capacity, of 65,000 pounds. The locomotive complete weighs almost 250 tons without its mammoth tender



2-8-0. A drawing of the famous locomotive turned out in huge quantities by U.S. makers for war work abroad. Locomotive types are designated by numbers, referring to the count of wheels in the front truck, the driving wheels, and the wheels under the cab (in this case none, hence the "0"). Without its eight-wheeled, 22-foot tender, the 2-8-0 weighs between 60 and 70 tons and is 35 feet long



the very critical days of early 1943, the MRS moved in. It found that the British and American locomotives in use were not powerful enough to negotiate a roadbed with hairpin turns at a speed necessary to meet the Russian target of supply at the Caspian Sea. It found that the Persian Gulf port would not accommodate the deep-draft ships streaming over from America.

A fleet of Diesel-electrics—"streetcars," in railroad slang—was ordered. A hundred miles of new line was built from a whistle stop called Awaz to a better port at Khorramshahr. By May "the Shah's toy" was

delivering 18 percent more tonnage than the Russians had specified, notwithstanding the fact that natives complicated operations by stealing the oiled stuffing out of journal boxes to make camp fires.

The Normandy operation was something else. Never in a major war had rolling stock been landed on a shore where the enemy stood at the battlements.

That is where a man named Sidney H. Bingham comes in. In peacetime Bingham ran the New York subways. Emphatic, imaginative, he was put into a uniform with Transportation Corps insignia on his lapels

2-10-0. A huge locomotive of a type built for Russia rolls out of the shop to be knocked down and shipped. It has a 60-inch gauge

SWITCH ENGINE. The stubby tugboat on rails is used chiefly at ports by Military Railway Service



My Sweetheart Is a BLACK WIDOW

Fly with a night-fighter ace
and see how the famous P-61
plays blindman's buff with Jap
raiders—and wins every time!

By
MAJ. CARROLL C. SMITH

As told to **ANDREW R. BOONE**

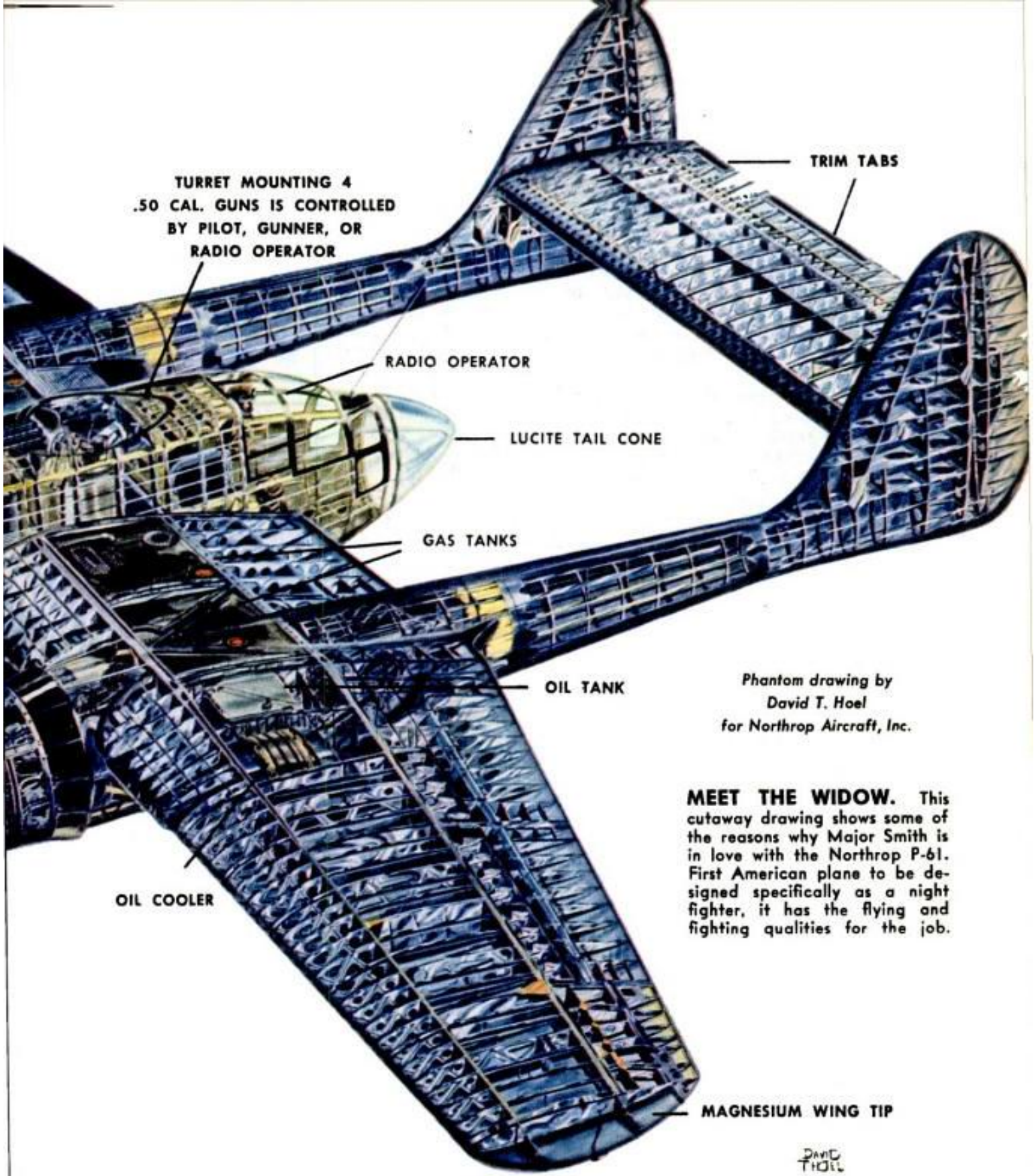
THE AUTHOR qualified as the first night-fighter ace of the war when he bagged seven Japs in four of his 139 night missions in the Pacific. Five of the enemy planes fell to the 20-mm. cannon of his Black Widow "Time's a-Wastin'," and he got the two others when he was piloting P-38's. He has been awarded the Air Medal with one cluster, and recommended for the Silver Star and Distinguished Flying Cross. Twenty-seven years old, he is now serving on the staff of the Fourth Air Force Night Fighter School, at Hammer Field, Calif.



THAT Jap pilot tooling his twin-engine Dinah Mark II toward our airstrip at Morotai wasn't worried. At 8,000 feet his fighter was invisible (he thought), his 20-mm. cannon and 7.7-mm. machine guns would protect him in a clinch, and as a last resort he could climb a mile in 90 seconds or so to evade us.

He hadn't the foggiest notion that Lt. Phil Porter and I were floating in the

POPULAR SCIENCE



TURRET MOUNTING 4
.50 CAL. GUNS IS CONTROLLED
BY PILOT, GUNNER, OR
RADIO OPERATOR

RADIO OPERATOR

LUCITE TAIL CONE

GAS TANKS

OIL TANK

OIL COOLER

TRIM TABS

Phantom drawing by
David T. Hoel
for Northrop Aircraft, Inc.

MEET THE WIDOW. This cutaway drawing shows some of the reasons why Major Smith is in love with the Northrop P-61. First American plane to be designed specifically as a night fighter, it has the flying and fighting qualities for the job.

MAGNESIUM WING TIP

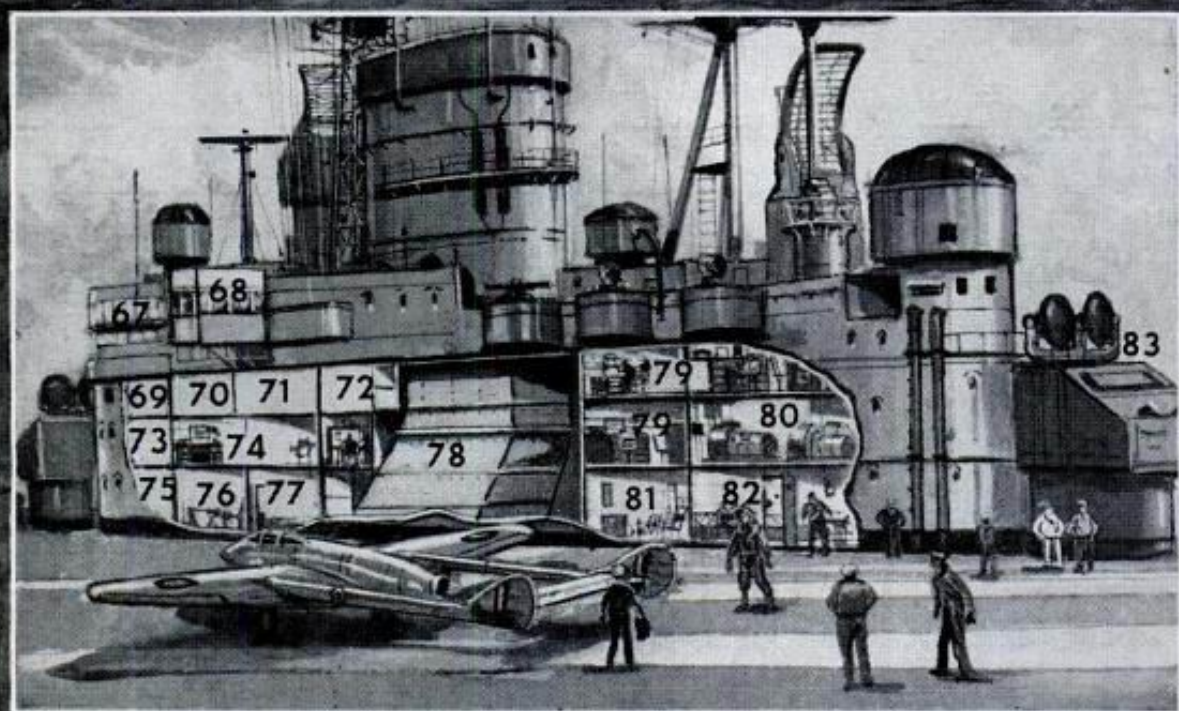
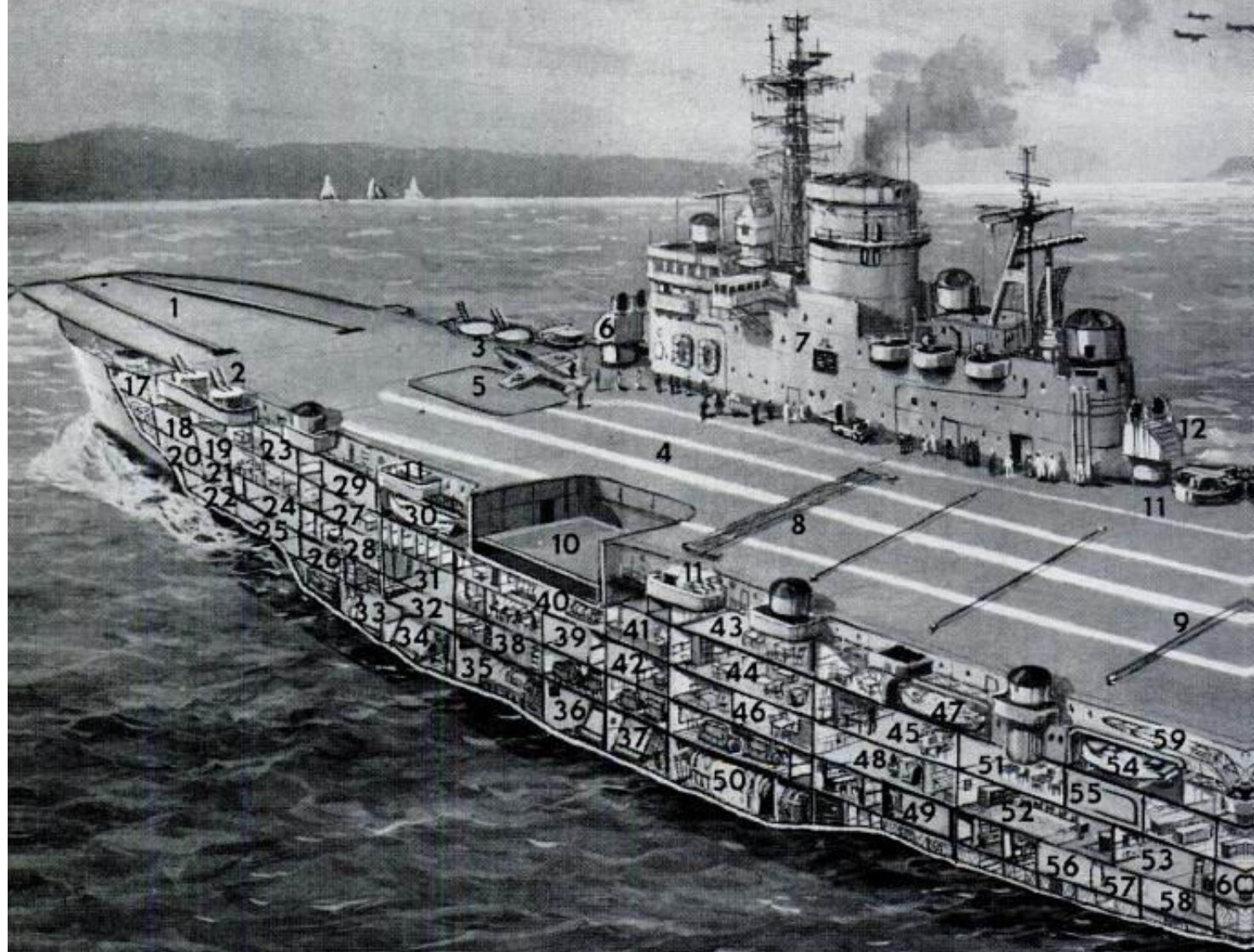
DAVID
HOEL

moonlit night over the field, throttled to minimum cruising. We were saving gas, to make sure we'd have plenty in case a Nip came over.

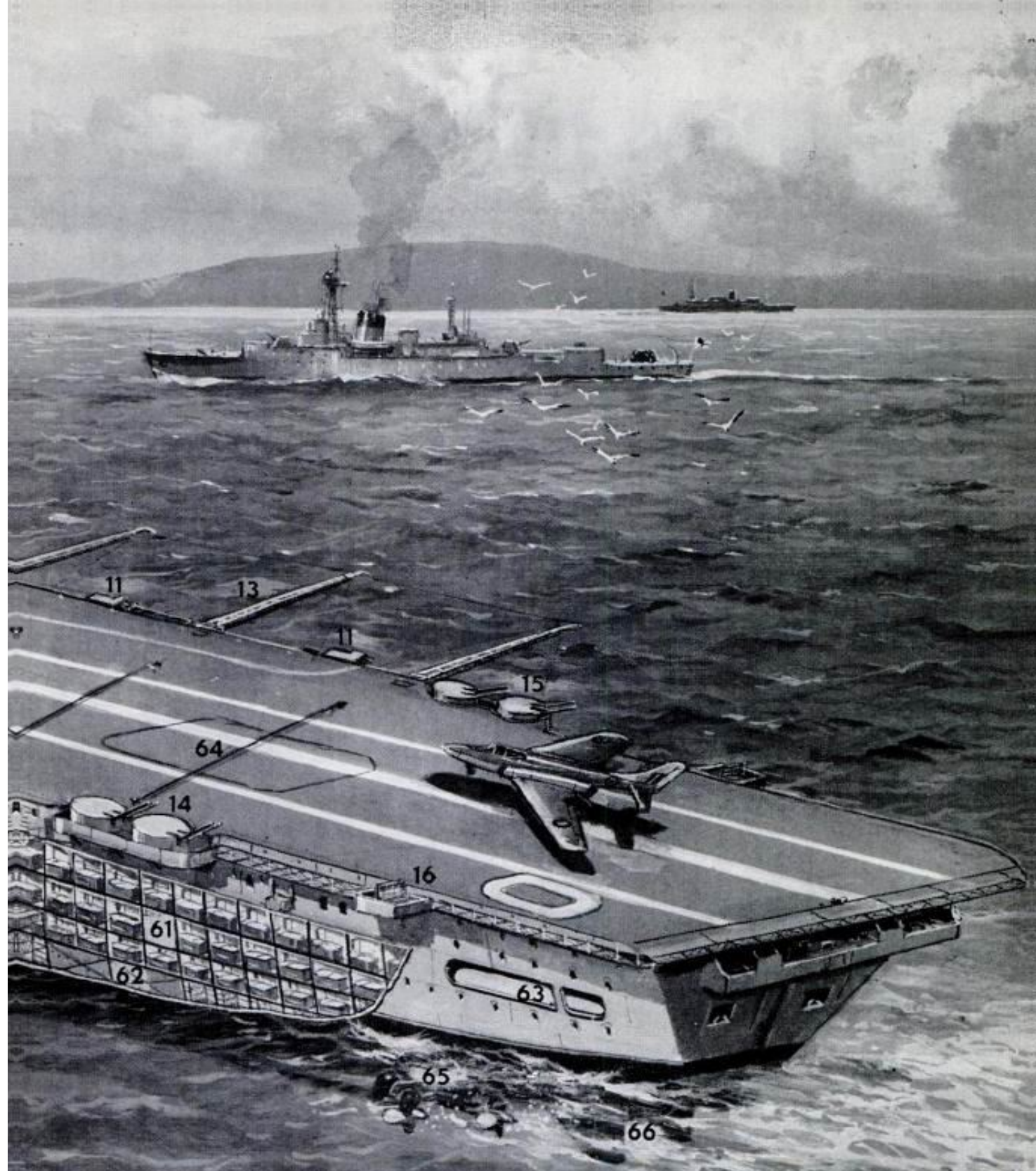
He still wasn't worried when our ground control picked him up and flashed the first order: "Darkie One from Nightie. Climb to 8,000 . . . course two zero zero . . . range about 12 miles." Instantly I turned my attention to my instruments. Phil

shouted instructions as I swung the Black Widow onto the new heading. I flipped on the water injection to pull another six inches of manifold pressure. That meant 200 to 300 more horsepower from the big Pratt & Whitneys . . . 300 feet a minute faster climb.

While ground control continued directing us toward the incoming fighter, I climbed and turned with everything jammed



CHAVIS
1955



BRITISH AIRCRAFT CARRIER ARK ROYAL

1. steam catapults; 2, 3. dual-purpose guns (4.5-inch); 4. angled flight deck; 5. aircraft lift; 6. director tower; 7. superstructure; 8. arrestor net (lowered); 9. arrestor wires; 10. deck-edge lift; 11. Bofors guns; 12. director tower; 13. radio masts lowered; 14, 15. dual-purpose guns (4.5-inch); 16. deck-landing controller; 17. mess; 18. mess; 19. dining hall; 20. mess; 21. pantry; 22. laundry; 23. air workshops; 24. hospital; 25. stores; 26. forward remote-control room; 27. mess; 28. offices; 29. showers; 30. 32-foot cutter; 31. stores; 32. mechanics' mess; 33, 34. forward boiler rooms; 35. forward port engine room; 36, 37. after port boiler rooms; 38. engineers' offices; 39. mechanics' mess; 40. lift machinery; 41. wash place; 42. lobby; 43. mess; 44. mess; 45. dining hall; 46. recreation rooms; 47.

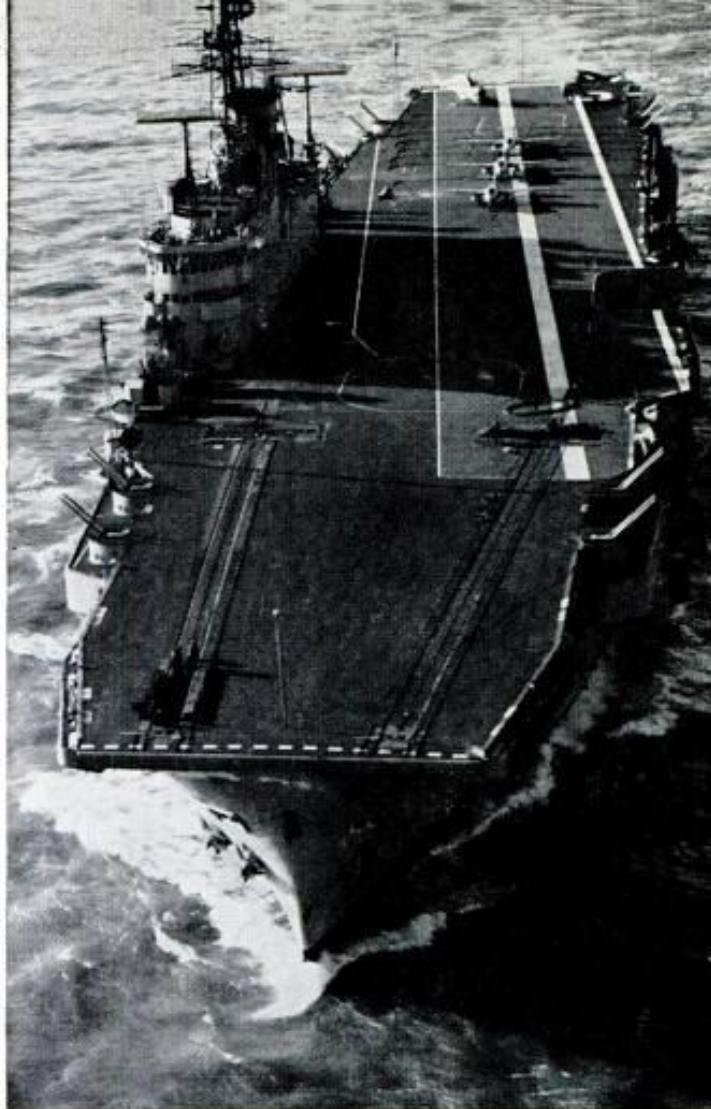
36-foot speedboat; 48. mess; 49. after remote-control room; 50. after port engine room; 51. mess; 52. dining room; 53. ante-room; 54. 36-foot speedboat; 55. open space; 56. prison; 57. stores; 58. refrigerated stores; 59. crane; 60. captain's lower office; 61. officers' cabins; 62. fresh-water tanks; 63. quarter-deck; 64. after aircraft lift; 65. twin propellers; 66. twin rudders. SUPERSTRUCTURE CUTAWAY: 67. bridge; 68. flying commander's bridge; 69. admiral's office; 70. captain's sea cabin; 71. navigation officers' sea cabin; 72. control room; 73. admiral's sea cabins; 74. executive officers' sea cabins; 75. squadron officers' cabin; 76. planning rooms; 77. switch room; 78. boiler uptakes; 79. operations rooms; 80. fan machinery; 81. briefing room; 82. ready room; 83. fire-control tower

Britain's Atom-Age Carrier

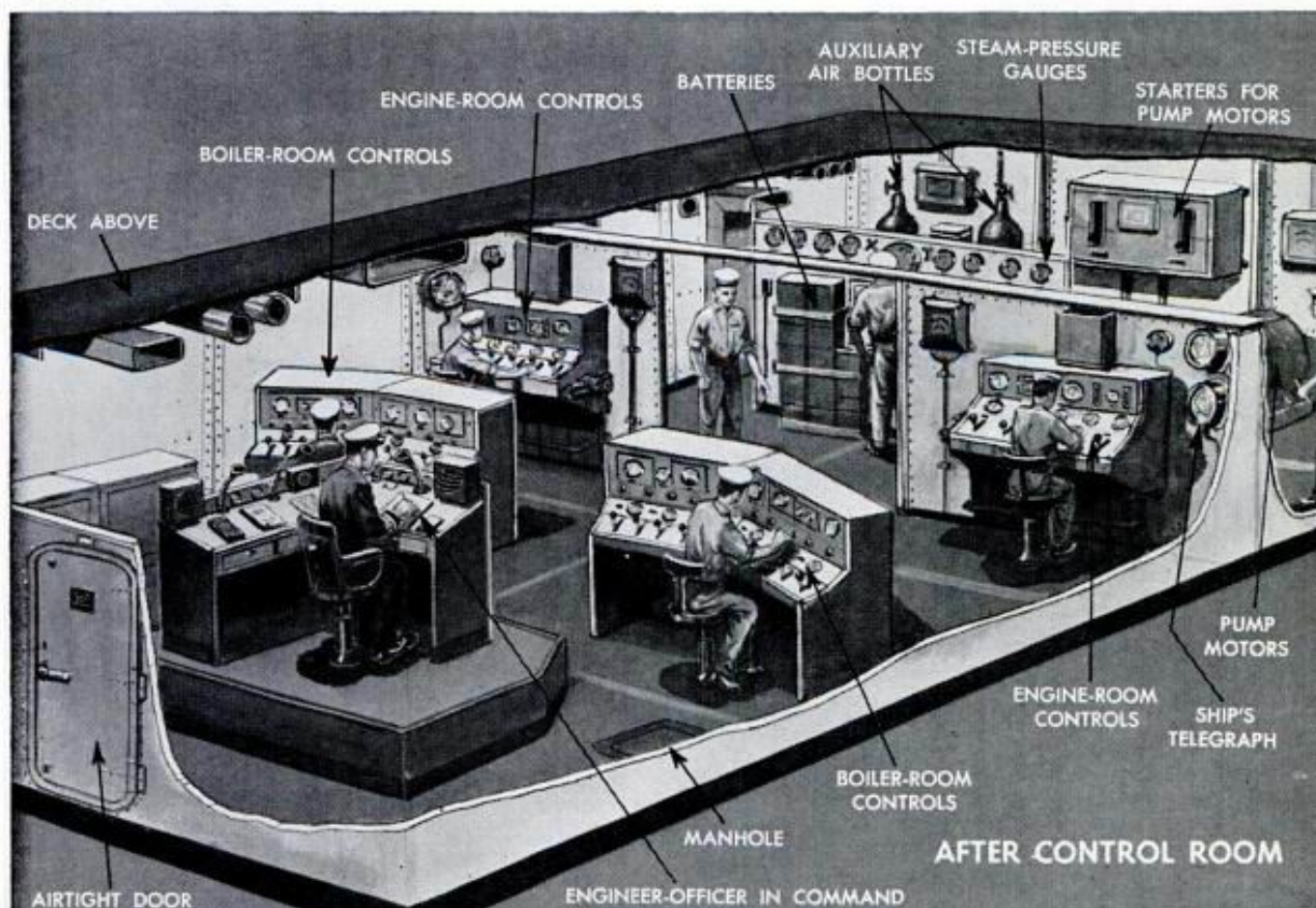
BRITAIN'S latest aircraft carrier, the *Ark Royal*, will be able to launch an atomic attack or weather the effects of a nearby atomic explosion.

After an atomic attack, the *Ark Royal*'s boilers and engines can be run by remote control from hermetically sealed and air-conditioned rooms. Provisions were made for clearing the engine rooms of personnel because the engines would suck in huge quantities of radioactive air. Two remote-control rooms, one forward and one aft, allow the crew to control engines and boilers while the ship speeds out of the contaminated area. Meanwhile, spray nozzles wash the exposed deck.

The vessel carries 100 aircraft and 2200 officers and men. The largest carrier in the British fleet, it has a standard displacement of 36,800 tons (half that of the USS *Forrestal*) and a length of 808 feet. It has two steam catapults, an angled deck and a mirror landing guide. A cutaway drawing of the aircraft carrier appears on the following pages. ★ ★ ★



Ark Royal has top speed of over 30 knots. Keel of the recently completed ship was laid May 3, 1943. Modifications to make it most modern carrier afloat slowed delivery. Below, a remote-control center



SWEDEN'S NAVY JOINS THE UNDERGROUND



American Swedish News Exchange photo

Top, tunnel is blasted through solid rock to join other tunnels in a network of underground shelters

By G. Alison Raymond

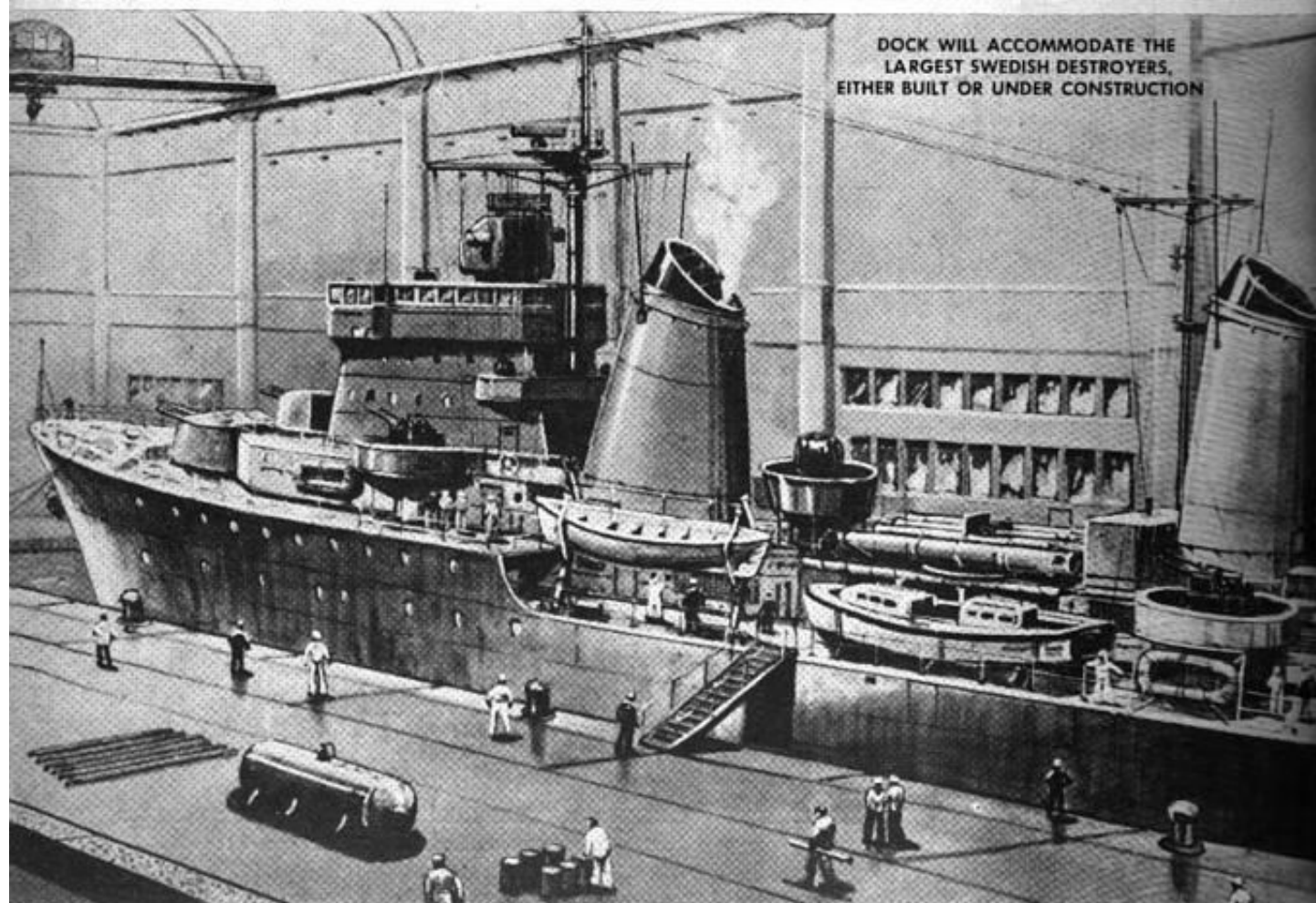
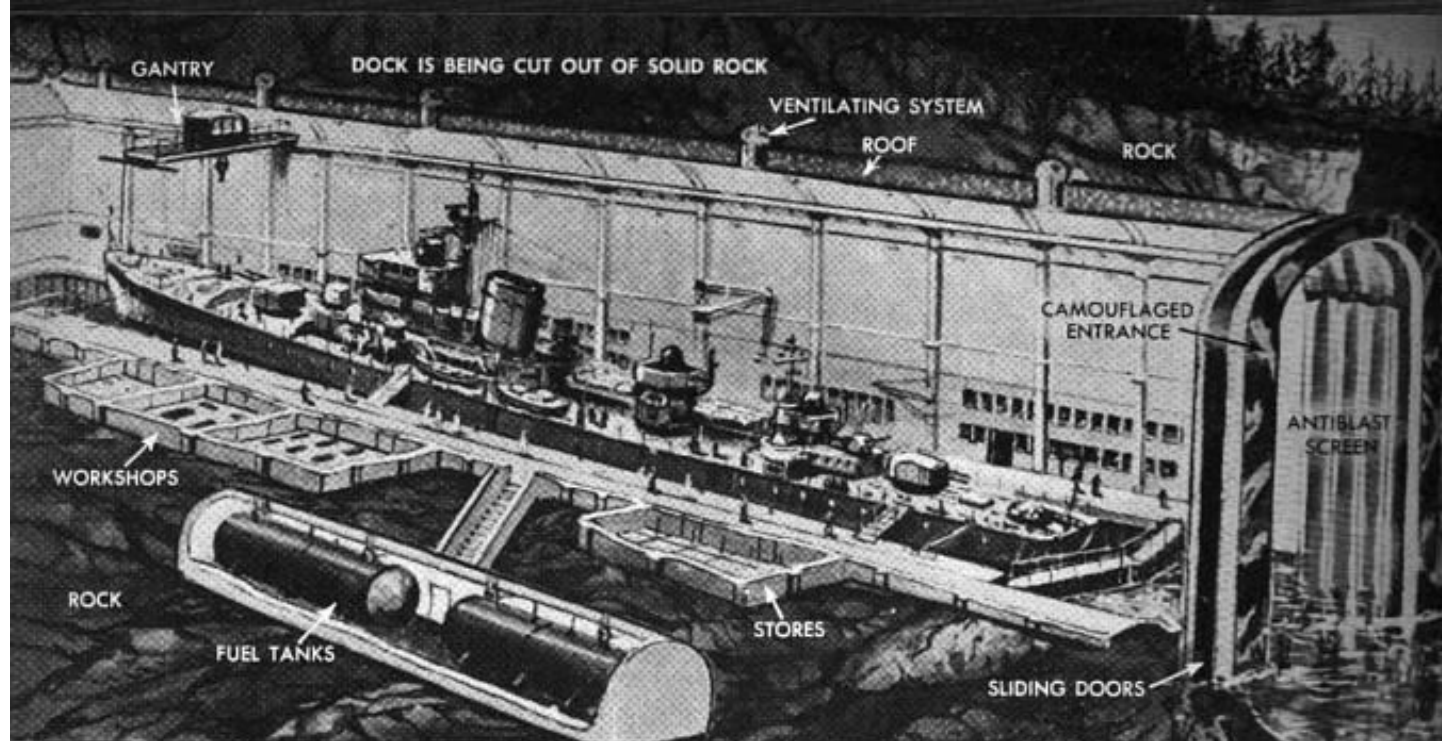
TUNNELS ARE not new; but structures excavated from solid rock that are cheaper than equivalent structures on the surface—that indeed is news. In this age of atomic and hydrogen weapons, developments along these lines are of substantial interest to industrial, military and government officials throughout the world.

Less than 10 years ago no engineer would willingly accept that tedious, tremendously expensive undertaking of tunneling except as a last resort. Since then, however, new equipment and new techniques have inspired a new concept of underground engineering design.

Sweden has been the leading pioneer in

developing methods which rip rock from the depths of the earth quickly and easily, prompting one Swedish engineer to say, "We have lost our respect for hard rock."

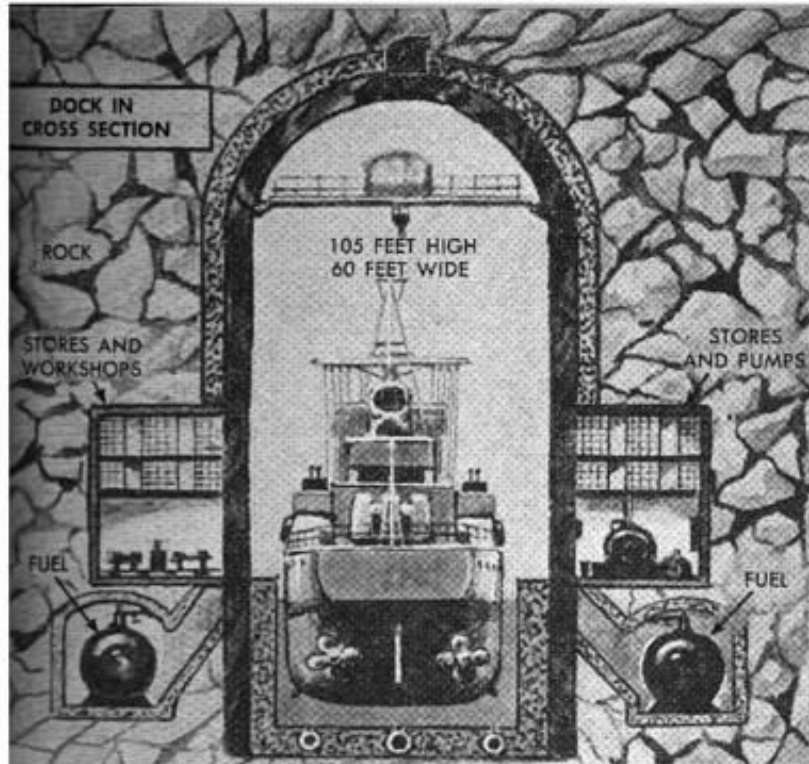
Sweden has already put several power stations and a considerable number of her factories underground; even her armed forces are based deep beneath hundreds of feet of solid granite. Sweden's navy, for example, is housed in huge, coastal, rock tunnels which disappear straight into the mountains directly from the sea. These tunnels can house destroyers of 2600 tons as well as submarines and other units, providing adequate docks for them all. Heavy gateways and pockets have been blasted at



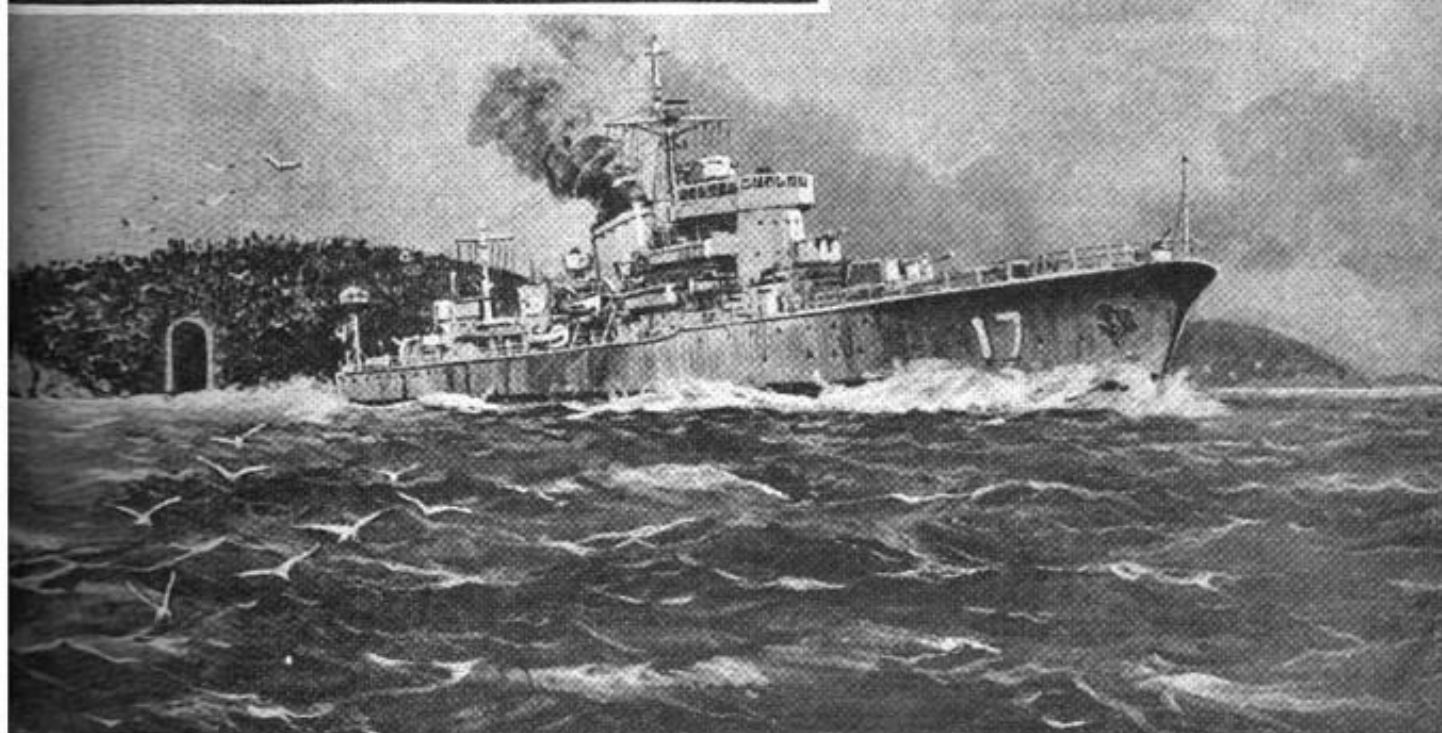
oblique angles into the rock to protect the tunnels against the impact of air and water pressure in case of enemy attack. So far, the largest tunnel is 96 feet high and 57 feet wide. Not only docks, but also repair depots, workshops, storage areas and living quarters for personnel have already been built deep in the granite. Gradually Sweden plans to house more and more of her combat strength in similar tunnels.

The air force also is well protected with

underground hangars for an estimated 1500 planes. There are permanent installations for the coast artillery. A control center for high military and civil authorities has been buried far below the earth's surface, as well as radar controls, workshops, supply depots, fortifications and military rock shelters. About 500 underground shelters are either completed or well underway. Millions of cubic feet of granite have been steadily blasted away since the end of

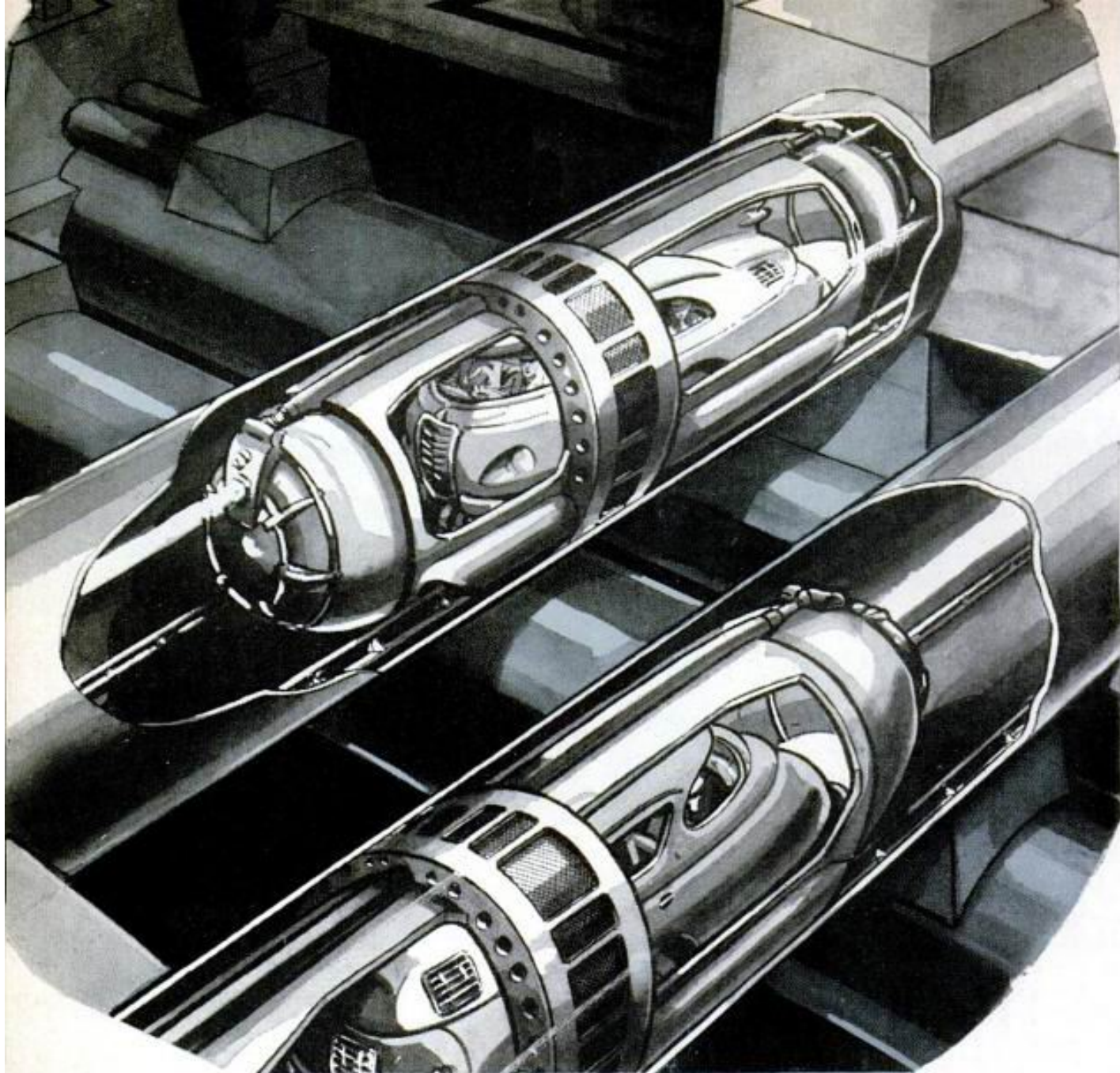


SWEDISH DESTROYER LEAVES THE UNDERGROUND DOCK. DARKENED DOCK AND CAMOUFLAGED ENTRANCE WILL MAKE THE DOOR ALMOST INVISIBLE AGAINST THE PINE-COVERED ISLAND



World War II, making a close network of hidden chambers along the entire Swedish coast and at certain strategic inland centers. Near the Arctic Circle one of the world's largest power plants has been buried far beneath the surface. With its generator as large as a cathedral, 380,000-volt Haespranget lies, as do power plants in Canada and the western part of the United States, so deep within the bowels of the earth that even a direct hit would not de-

stroy it. In this age of rapid oil consumption it is exceedingly difficult to store enough fuel to keep a nation going, but Sweden has gone a long way in this direction. Enormous underground cement tanks, lined with metal, have been built in scattered locations. In some areas it has been possible to take over abandoned mines, converting them into almost bottomless storage tanks where increasing supplies of fuel are being hidden away.



Honeywell engineer predicts that by A.D. 2000 cars will zip through network of crashproof pneumatic tubes



It was based on a simple scientific principle: Butz knew that heat makes most substances expand, cold makes them contract; and brass and rubber have widely different rates of expansion and contraction. He cemented paper-thin strips of the two materials together, fastened down one end of the brass-rubber strip, placed the other between two electrical contacts a fraction of an inch apart. Then he ran wires from the contacts to an electric motor he had attached to the furnace dampers. As his house became warm, the strip began warping toward the contact which would cause the motor to close the dampers; as the house cooled, the strip warped back to the other contact, opening the dampers to supply the house with more heat.

Today, 74 years later, the principle Butz worked with has been parlayed into a company that makes 12,740 automatic devices which reach into every facet of life, and range in price from 30 cents for a simple electrical switch to \$2,500,000 for enormously complex equipment which performs office and clerical routine completely, quickly and precisely.

For the first 40 years of its existence the firm, then known as the Minneapolis Heat Regulator Company, concentrated on making the controls which automatically regulate temperatures in tens of millions of homes throughout the world today. But following a merger in 1927 with the

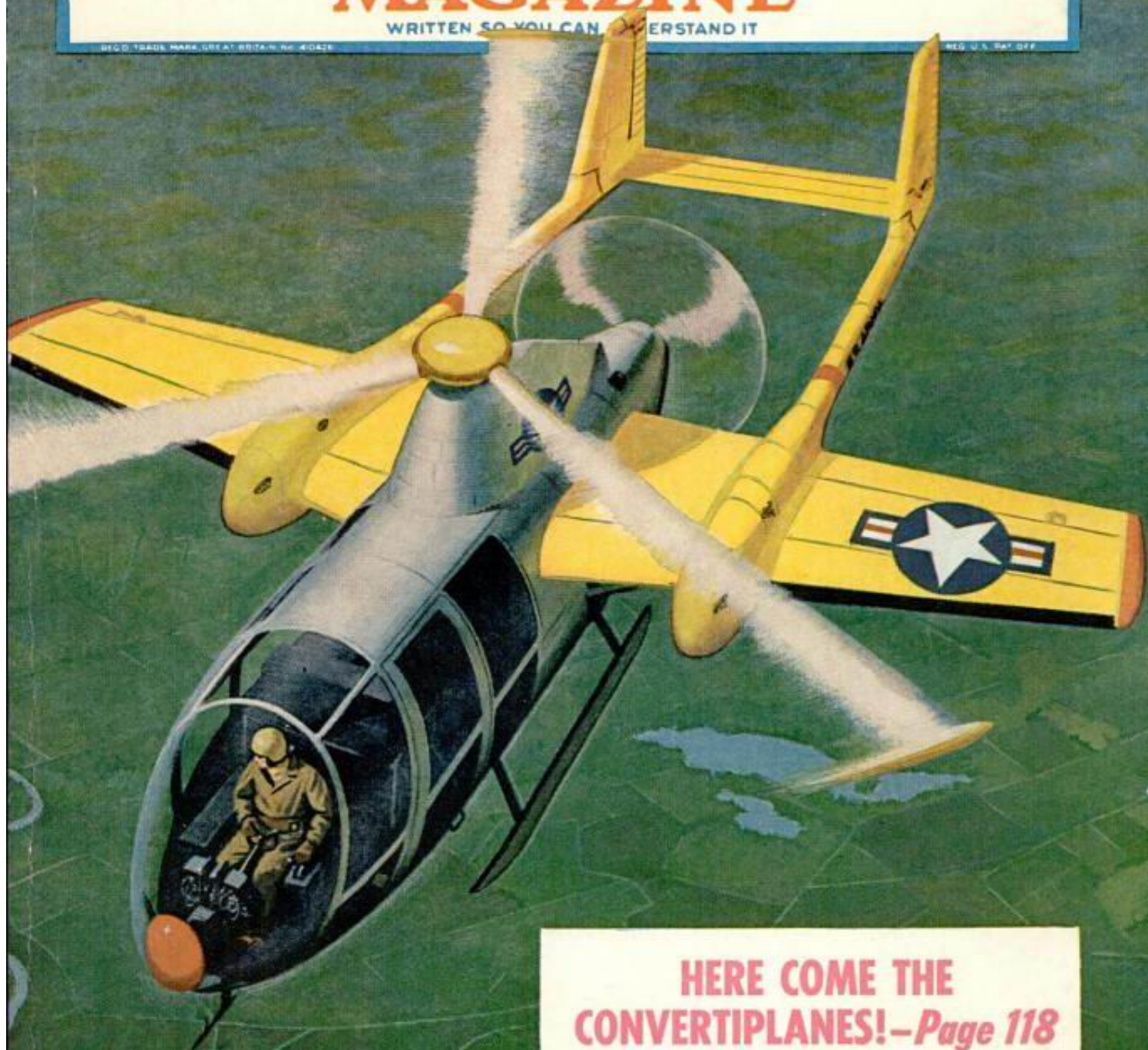
This is probably the first heating regulator ever produced, putting the company in business

POPULAR MECHANICS MAGAZINE

WRITTEN SO YOU CAN UNDERSTAND IT

REG. TRADE MARK, GREAT BRITAIN NO. 40428

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**HERE COME THE
CONVERTIPLANES!—Page 118**

**What the Owners Say About the
'54 BUICK**

For the Craftsman
Build Your Own Porch and Breezeway

Материал, защищенный авторскими правами



Any day now you may see a strange craft take off like a helicopter, drive forward like an airplane. In factories from Long Island to Los Angeles, engineers are racing to be first with this new breed of aircraft

HERE COME THE

By Richard F. Dempewolff

YOU HOP IN the family aircraft on the back lawn, "rev" up the rotor and hoist yourself by direct lift to whatever altitude you desire. Then, disengage the clutch, shift to forward propulsion, and off the "flivver" goes at 200 or 300 miles per hour like a true airplane. At your destination you simply shift back to rotor, hover around until you spot a clear space no larger than the plane itself. Then tamp out your cigarette in the instrument panel ash tray and gently helicopter yourself earthward like an elevator settling to the ground floor.

It sounds like a dream for the year 2000 and perhaps it will be that long before your children and mine can actually buy and fly such wonder planes at a reasonable cost. But the craft itself—known as the "convertiplane"—is far from dream stuff. In aviation plants from the tip of Long Island to the Pacific Coast, practical aerodynamicists are juggling a wide variety of rotors, wings and propellers to achieve this kind of convertible aircraft. They're running wind-tunnel tests on aeronautical freaks that may start the flying world off in a new

direction. Ramjets, pulse jets, turbojets and piston engines are being tried alone and in combination on a large number of unbelievable configurations.

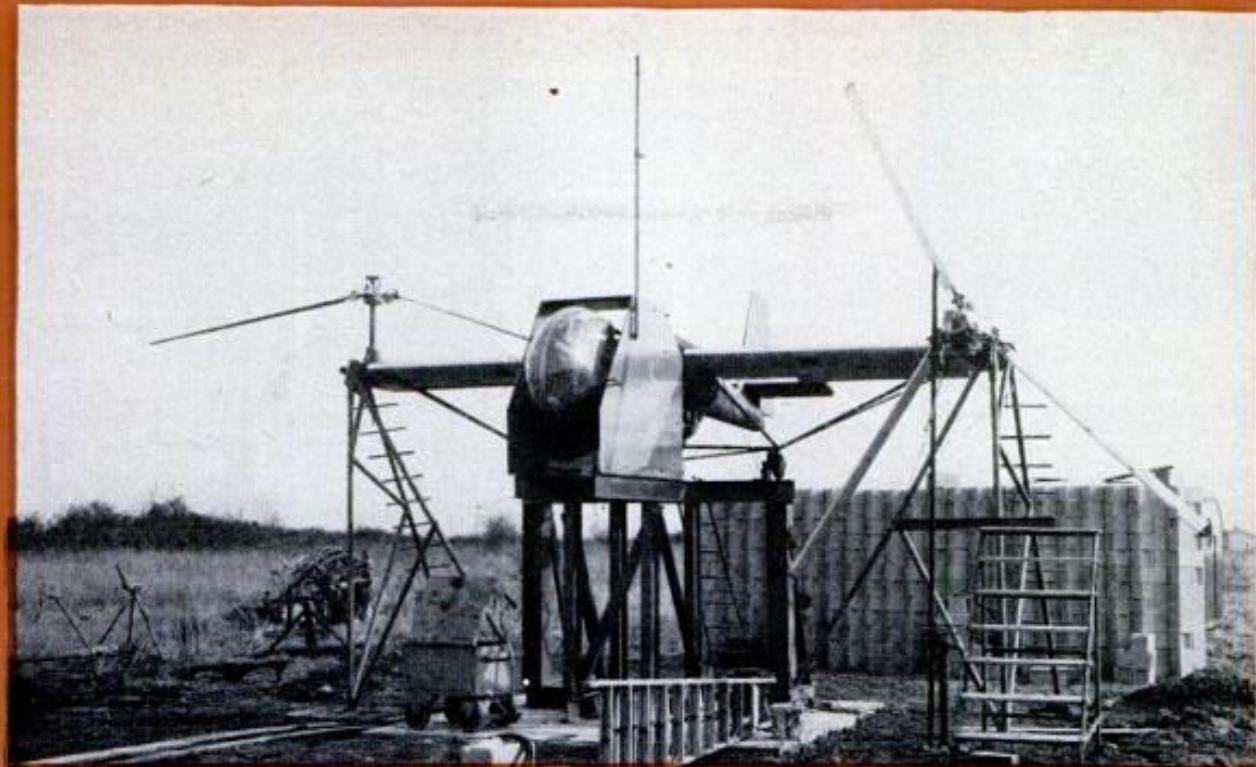
Two years ago, the Department of Defense, impressed with the helicopter's service in Korea but not content with its speed (about 150 miles per hour maximum), assigned convertiplane contracts to McDonnell for the XV-1, Bell for the XV-3 and Sikorsky. The "X" is for experimental, the "V" for vertical.

The rotor of the McDonnell XV-1, to be flight tested this summer, is powered by pressure jet units at the tips of its three blades. A piston engine supplies air to the jet during vertical flight and turns a propeller during forward flight.

Meantime, several privately built convertiplanes already have flown, other prototypes are built and are undergoing ground tests prior to flying this summer.

Convertiplaners argue spiritedly about the best way of achieving the craft's enticing possibilities and there are hundreds of fanciful ideas. Out behind a rented hangar





Transcendental's tilting-rotor plane is still undergoing ground tests, will probably take to the air this year

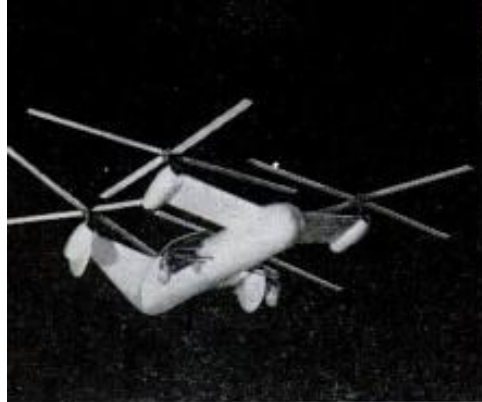
CONVERTIPLANES

Pivoting wings of Wayne University model are vertical for ascension and horizontal for fast forward flight

at Bellanca Airport, near Wilmington, Del., Bill Cobey and Mario Guerrieri of Transcendental Aircraft Corp. have been running ground tests for two years on a genuine convertiplane that looks for all the world like an overgrown dragonfly. The pilot sits in a big blister up in the nose. Behind him are the engine and transmission, shafted to a 15-foot rotor on the tip of each stubby wing. Working in counter rotation, they raise or lower the craft like a helicopter. Once in the air, the pilot shoves in the conversion control—a simple lever—and a pair of electric screw jacks slowly moves both rotors to forward position.—Presto! It's an airplane. To land, the procedure is reversed.

Cobey and Len Leone, president and vice-president of the company respectively, admit there are plenty of problems involved in this type of convertiplane and are in no hurry to take their craft off the ground until all tests are completed (probably this year). But they know what she'll do: "Everything a helicopter will do, plus 170 miles per hour in forward speed," says





Compound helicopter being built by Convertawings has stubby wings for lift in forward flight

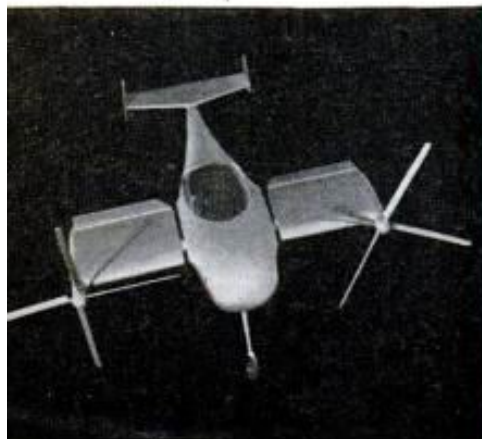


Rotor of Herrick model becomes the main wing for forward flight



Army hospital plane has coaxial rotors, forward props on wings

Single rear engine drives rotors of a pivoting-wing Convertawing



Cobey. "There will be no limit in a larger prop and piston-engine version. It will perform within 10 percent efficiency of any comparable-size airplane in forward speed and will handle a payload of 22 percent of its gross weight."

The Bell convertiplane for the Air Force, due out from under wraps this summer, is nearly identical with Transcendental's craft, only bigger, with seats for two or three passengers in its long, Plexiglas nose. Its wing-tip rotors hinge up and down in slotted, streamlined nacelles. Under its belly are three long skids in place of tricycle landing gear.

A great many tilting-rotor designs have been proposed by inventors—some in which rotors are stacked fore and aft, then convert so the front one hinges forward to become a nose propeller and the rear one hinges back to become a pusher-type, with blade pitch reversed. In others—such as a model produced at Wayne University, and the tiny Model B convertiplane designed by a company named Convertawings, in Amityville, L. I., two rotors jut like propellers from the leading edge of each wing.

When the pilot wants to take off, both wings swivel so the rotors face upward. Once in the air, the pilot tilts his wings back to normal airplane position and the rotors turn with them to become propellers.

Convertawings has no immediate plans for building the ship, but President Dave Kaplan can show you a handsome silver model of the two-seater design under development with a whirling-arm test stand.

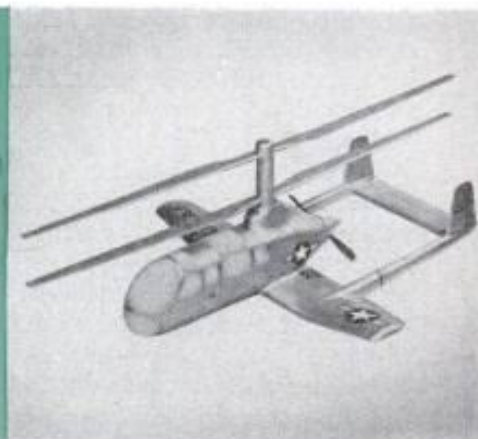
Meanwhile, Kaplan and his men are building a fantastic-looking "Quadrotor"—a compound helicopter with four rotors in double tandem, stub wings and Jacobs solid extruded aluminum blades. "The Quad design," says Dave, "lets us use much smaller blades to work on the same air mass. It may point the way to huge transport helicopters with speeds competing with airplanes." The Quad should be ready this year, and after a spell of testing will be sold for crop dusting, or some similar duty, Convertawings hopes. If it works, and sells, they'll build a whopping quad transport and, perhaps, the little convertiplane sky flivver.

In case you don't care for old-fashioned piston engines in these planes of tomorrow, inventor Alfred I. Roman in New York can build just the convertiplane for you—if you'll put up the money. Sketches of Mr. Roman's brain child show a highly streamlined affair that looks like a supersonic jet fighter with rakish, swept-back wings. For vertical flight, the wings are tipped perpendicular to the plane and a battery of rockets on the wings' undersides whams it skyward. If you prefer something more leisurely, you might try

Tilting-rotor Bell plane being built for Air Force holds three passengers
John Zimmerman photo



Twin-tailed Gyrodyne model has coaxial rotors, pusher propeller



Roman's alternate version with jet-driven rotors on the wing tips. It works on the tilting-wing rotor principle.

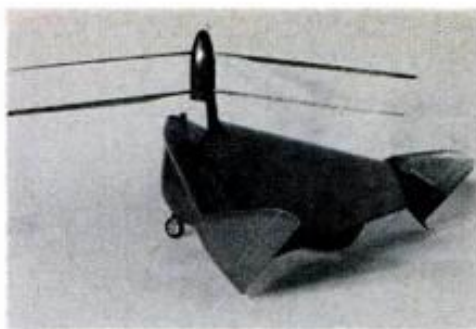
Of all the tilting-rotor-type designs, one of the most unique comes from California. At North American Aviation (which hasn't anything to do with the project), research engineer Frank A. Dobson and some fellow workers have developed a mosquito-like little delta-wing craft with two vertical fins and a pair of 16-foot three-bladed, contrarotating propellers on a single hub that juts from the nose. In this position, the tiny craft is a fast-flying (187 miles per hour) triangular affair powered by twin McCulloch engines whipping up 70 horsepower each. The plane carries two passengers and Dobson envisions it as a back-yard family craft or a military liaison vehicle.

When Pop climbs in to take off, the craft sits on a pair of skids under its low aft end and swivel wheels under the nose. The hinged nose shaft is pointed skyward, with stacked rotors whirling in opposite directions. If Junior is hopping around, the thing won't take off but will pivot around on its skids until he climbs into the seat and the center of gravity is established beneath the rotor. Then, up she goes, nose high, like a helicopter. At proper altitude, the nose hub goes down and the craft zooms away at a 170-mile-per-hour cruising speed. To land, the process is reversed, and the craft helicopters to earth at a maximum forward air speed of 20 miles per hour.

At last report, Dobson and his friends were building a prototype. If it is successful, he expects to try a military type of jet machine that he believes will do 700 miles per hour.

Plenty of people in the convertiplane business think that tilting wings and rotors are far too complex and impractical. Even enthusiasts admit they pose terrific problems. Cobey and Leone smile when anyone talks about flying one this year. "There's a new vibration problem for every degree of tilt," says Cobey. He recalls wryly that, during an early tilt test, ground resonance (sympathetic vibrations that sometimes wreck helicopters revving up on the ground) set in and shook the little plane apart. Months were lost rebuilding it. "We admit our failures as well as our successes," says Cobey.

Other experts claim that a rotor makes about the



Rotors of Dobson Delta Wing tilt forward



Rotor blades of Gyroliner model telescope inward to reduce drag in forward flight

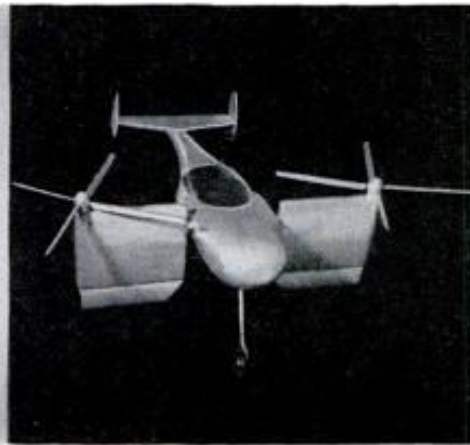


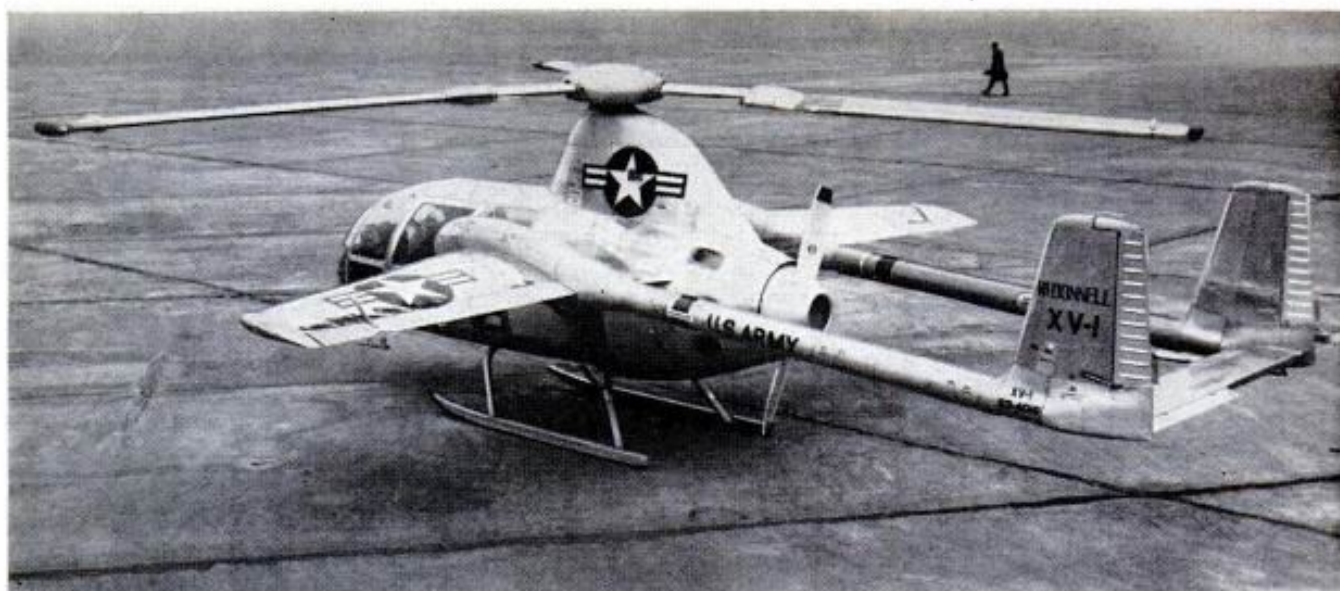
Rectangular ramjets on rotor tips work fine but waste fuel, Gyrodyne decided

Coaxial rotors of the Navy model fold for storage on carrier

Gyrodyne model has rotors and two forward piston engines

Pivoting-wing model shown on opposite page in position for vertical ascension





First U.S. military convertiplane is the XV-1, built by McDonnell. Pusher prop and rotor-tip jets power it

most inefficient kind of propeller man could devise. Many critics are not opposed to convertiplanes. They go for the type that has separate rotors and forward power units.

In St. James, L. I., Peter Papadakos, president of the Gyrodyne Company of America, has plans for a half dozen such convertiplanes. One is a 72-passenger Gyroliner, with two 88-foot, four-blade rotors that contrarotate like big choppers. Turboprop engines in the small wings provide forward speed as well as rotor power. She'll cruise at 230 and rise at 2350 feet per minute. Papadakos is confident his ship will perform, because he's one of the few people who have actually flown a prototype. It happened in 1951 when test pilot Jim Ryan buzzed around in Gyrodyne's coaxial helicopter, with a forward engine rigged on each side.

In Gyrodyne's models, the rotors go at all times. "They're under minimum power in forward flight just to offset drag," explains Papadakos. "The wings take much of the lift in forward flight."

The company also has plans for smaller craft with folding rotors for Navy ships, telescoping rotors for big liners and ramjet rotors for a military version. Some have two blades, some four. So far, none has been built, but the big Gyroliner is a special contract that may one day take to the air.

Convertiplanes in which the rotor is separate from the forward propellers can be fairly simple or ultrafancy. E. Burke Wilford, national chairman of the Convertible Aircraft Pioneers, is building a working prototype at Townson Field, near Trenton, N. J. He is simply putting a four-bladed rotor, driven by tip ramjets, on a modified Aeronca frame. He expects that his co-

worker and pilot, George Townson, will take off in it this year. The rotor will hoist the plane up, then go into free wheeling as the forward propeller picks up speed and wings take over the job of supplying lift. Hence, the craft will function as helicopter, autogyro and airplane in successive stages.

If anyone can fly it, Townson can. He made over 100 conversions in the granddaddy of all convertiplanes back in 1937. That machine, designed and built by the "father of the convertiplane," an inventor named Gerard Herrick of New York, president of the Convertiplane Corporation, was a tricky combination of low-wing monoplane with a free-wheeling, two-bladed rotor on top. When locked in position, the rotor became a fixed wing. Townson would take off like an airplane, release the rotor in flight and come down like a 'gyro. He could take off and fly like an autogyro if he chose. The craft could also be flown as a biplane, but had to start off as one since, in this test ship, there was no way to stop the rotor in flight. Just how fast she'd get off was demonstrated in one early flight, when unexpected vibrations worried Townson and he set her down in somebody's back yard. He made an adjustment, let the rotor spin and took off between two houses with inches to spare. "It was morning and folks were having breakfast," he recalls. "Often wondered what those people thought when that weird whirlybird skimmed past their breakfast tables a few feet away."

Today, a whiter-haired but still enthusiastic Herrick has a new design on the same theme, which he'd like to build. His slick wind-tunnel model resembles a Flying Boxcar with twin booms and tail fins. It has stubby underwings and a long, thin



Free-wheeling rotor on 1937 Herrick test plane paved way for powered rotors. Plane took off like biplane, landed like autogyro

upper wing suspended on a center shaft. Each side of the top wing can be tilted for pitch. The entire span can either be locked, permitted to spin freely like a gigantic pin-wheel, or powered by ramjet on each tip. A pusher engine behind the cabin supplies forward speed once the craft is airborne.

In Herrick's office sits an odd mockup with rotor head and traction propeller—driven by electric motors—plus a complete set of working controls. "I take generals, admirals and industrialists for rides, so they get the idea," explains Herrick. A ride in the mock-up provides a graphic experience. Standing by the controls, the

(Continued to page 210)

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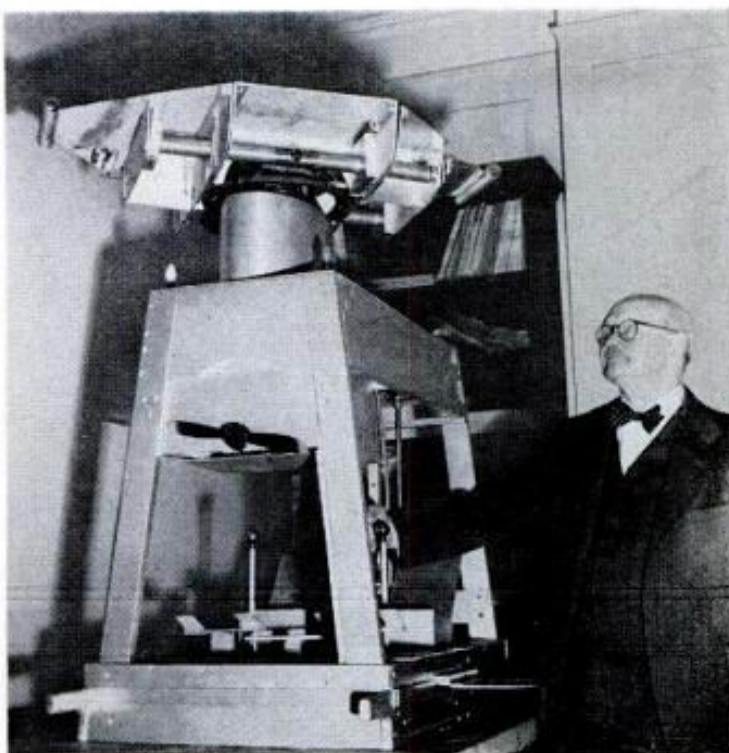


Flying Magazine photo
Flying prototype of British Fairey Gyrodyne has two forward propellers on tips of stub wings and a three-bladed rotor



Wingless convertiplane flown two years ago by Gyrodyne was a coaxial helicopter fitted with a pair of outrigger engines

Mockup of convertiplane in Herrick's office is equipped with complete controls, revolving rotor head and forward propeller



25589

ENTIRE SHIP GIVEN NEW COVERING
OF GOLD-BEATER'S SKINVERTICAL STEERING
RUDDERS

20 HELIUM BAGS

HORIZONTAL ELEVATING
RUDDERS

Science and Chance Play for High Stakes at the Top of the World

ONE important point to bear in mind in connection with the proposed polar exploration by dirigible is that in any case such an expedition can never be merely a spectacular feat of dashing adventure. It is essentially a useful undertaking of exploration, which, if successful, promises results of tremendous scientific and commercial importance.

In the accompanying article, Commander Green depicts vividly the almost unbelievable difficulties of arctic flying. He describes specific measures of the Navy to foresee these difficulties as far as possible before undertaking any flight as spectacular as has been proposed for the *Shenandoah*. Yet Uncle Sam's aviation experts know well that an infinite number of obstacles lie in wait for the forthcoming attempt to conquer the fierce air currents that swirl about the top of the world—obstacles that cannot be anticipated, nor guarded against by the most careful prepa-

ration. These unknown foes, as Commander Green points out, are reared by Chance, upon whose bounty those who dare the air in dirigibles are absolutely dependent for their success or failure. Witness the recent appalling disaster to the giant French dirigible *Dixmude*.

To be sure, the *Shenandoah* gave a splendid account of itself when it broke away recently from its mooring mast at Lakehurst, N. J. But such a ship cannot land as an airplane can. If its supply of fuel gives out, it is at the mercy of capricious air currents to a greater extent than even a balloon would be.

Maneuvering a dirigible near the ground is known to be virtually impossible. With helium gas supplying the lifting power, as in the case of the *Shenandoah*, great heights cannot be attained, because helium, expanding in rarefied atmosphere, would cause the

bag to explode. That is why the Navy's plans for the trip have been shaped so that she must circle the United States on her way to Nome; she cannot ascend to heights sufficient to clear the mountains that lie in the path of a direct route. The theoretical cruising range of a dirigible, as Commander Green points out, is reduced appreciably in any but calm air. In other words, Chance plays a not unimportant part.

So the crew of the *Shenandoah*, if they start on their voyage over the frozen seas of the north are facing all the dangers that ever confronted a polar expedition, plus unknown and uncounted dangers. They will be adventuring quite as much as the pioneer polar explorers whose expeditions almost invariably resulted in disaster.

The whole world will wish them success, but the world must not be carried away by the glamour that surrounds their hazardous and daring adventure.

degree or two variation on either side.

"We never seemed to get thawed out!" exclaimed a friend of mine who has done some flying in Spitzbergen.

Coupled with unvarying low temperature is the uncomfortable dampness of the arctic summer air.

Both of these features have a bearing on the choice of equipment for the expedition. Lubricating oils must be light enough, yet able to stand exposure to severe cold in case any engine is forced to remain north through the winter. All metal parts and fittings must be surfaced to withstand the effect of the air's high moisture content.

In allowing working time for such tasks as erection of mooring masts, hangars, and for repairs, a certain percentage always must be added for the numbing wind in which the men must labor. A freezing temperature is not severe. Often our carpenters work outdoors in colder weather than that. But in the north, where the sun's angle is low, where the cold wind's searching fingers never cease their prying, and where there is no such thing as noontime warmth, outdoor work becomes a serious problem indeed.

The aviator, confined to his narrow cockpit or control car, is supplied with special garments. Next to his



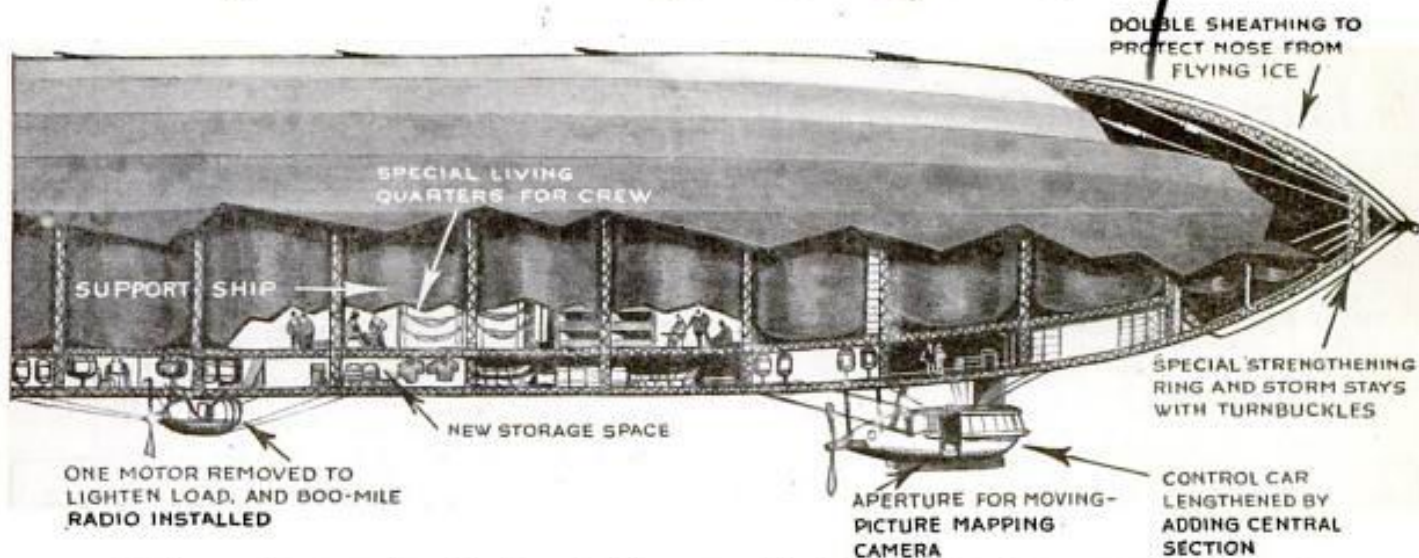
The contemplated route of the *Shenandoah* from her hangar at Lakehurst, N. J., to the proposed Alaskan base at Nome, thence 1560 miles to the North Pole. The total distance from Lakehurst to the Pole over this circuitous course is 6903 miles.

skin he wears ordinary woolen underwear. Then comes an electrically heated suit of asbestos-like material. Outside he wears a closely woven windproof coat of burberry or skin.

But cold can be anticipated. Wind cannot be. Winds are caused largely by heat. At the equator hot air rises and flows northward. Speaking broadly, in the arctic regions it cools and somewhere over the Polar Sea falls and pours south again. Theoretically it might thus be possible to fly high and have a fair wind to the Pole; then, by coming down near the earth's surface, to have the wind aft coming back.

The trouble is that we don't know just what to expect. The atmosphere at the poles is oblate or flattened, just as is the earth, only immensely more so. That is to say, while the atmosphere over the equator is thrown out by centrifugal force, near the Poles the reverse is true, and the depth of the atmosphere is tremendously decreased. Hence conditions of flying near the North Pole at an altitude of 5000 feet may differ greatly from those found over the United States at the same altitude.

Shortness of breath is a common result of rising high above the earth's surface. Most aviators breathe through their mouths at altitudes



This diagrammatic cut-away view of the *Shenandoah* shows proposed alterations designed not only to protect and aid the great air cruiser in battling polar gales and ice storms, but to provide comfortable quarters and scientific equipment for the long cruise of exploration

higher than 12,000 feet. At 15,000 feet the mere turning of the body to look around may aggravate breathlessness enormously. Since cold accentuates this respiratory weakness, it becomes one of the major problems of arctic flying.

One of the curious features of arctic navigation is the fact that the compass course toward the Pole from Point Bar-

row is a little south of west! The north magnetic pole lies in the North American archipelago above Canada. Toward it the compass needle points. Hence the paradoxical course that must be steered to reach the geographical pole.

There is a serious side to this matter. Static electricity is generally believed to be greater in polar regions than elsewhere

on the globe. The aurora depicts upper air conditions in this respect. Moreover, the directive force of the magnetic pole on the needle is slight in high latitudes. Altogether the compass is a frail assistant.

There are variations of the compass over the Polar Sea that never have been investigated. If a dirigible's navigator at the Pole should wish to head for Spitzbergen, 630 miles due south, he would have something to worry about when he began to set his course. Frequent sun observations would be his best bet. That is, if there were no arctic fog on the job to prevent him.

The thrilling possibility of the expedition is that we may find land. We must be prepared to find it, at any rate, and this opens up a whole new list of troubles.

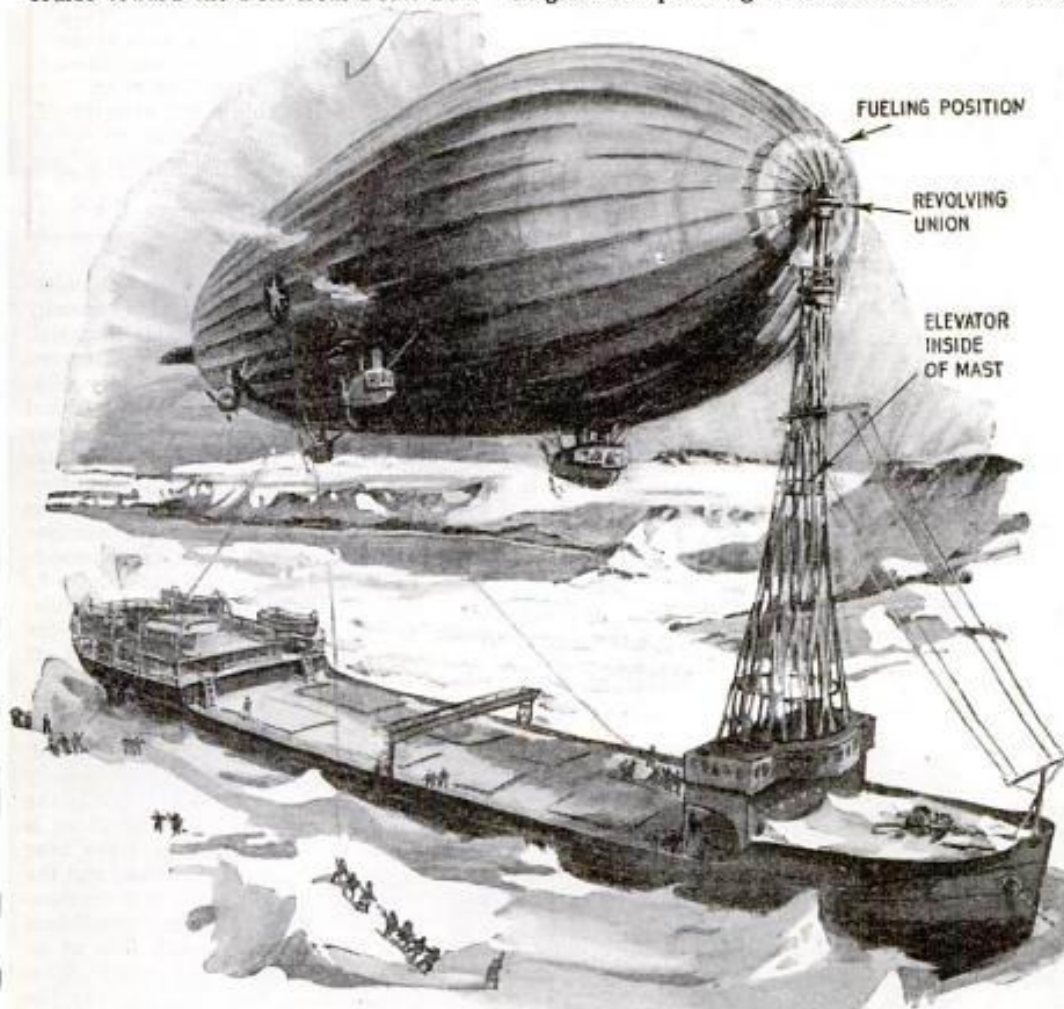
Dangers of Landing

Take the airplane. To fly safely over the polar pack a plane must be equipped with pontoons for landing in the water that forms on the ice in summer, or in the open water between floes. On these pontoons must be runners for landing on ice or snow, if necessary.

So far so good. But every arctic traveler knows that visibility conditions on the ice pack in broad daylight often are so trying that even a man afoot constantly stumbles over projecting nubbles. Diffused rays of the sun and lack of shadows make the roughest ice-field look smooth as a table from an altitude of 500 feet. To land under such conditions would mean to wreck one's plane.

A dirigible is even more severely handicapped. At the present point of progress in this form of airship, a safe

(Continued on page 150)



To provide dirigible anchorage in the Far North, the Navy is developing this type of mooring mast to be carried by supply ships. In its construction the lessons learned when the *Shenandoah* broke away from her mooring mast are being utilized.

The mast will be built to withstand an end-on pull greater than that produced by the 70-mile gale at Lakehurst. It will be equipped with elevators for the crew, and pipe lines for water and gasoline. Motor winches will carry heavy loads up to the ship

How the Followplane, gigantic seaplane cruiser to be constructed at Cleveland, Ohio, will appear when completed. This drawing is based on the designers' plans. The giant lines will be 170 feet long, and will be designed to carry 100 passengers and 2½ tons of express freight

Whole World in Race for Supremacy in the Air

By Donald Harris

THE swiftly moving airplane of today, with its one or two specially trained occupants, soon may share its dominance of the air with the slower-moving commercial liners and the more versatile helicopters of tomorrow, just as the specially constructed racing automobiles of 20 years ago moved over to give road room to the utilitarian cars of today.

Epochal Advances in Aviation

Epochal advances in aviation are in progress. The air flivver already is here. The helicopter and the gigantic air cruiser for freight and passengers are on the way.

In France recently M. Oehmichen flew for nine minutes in a helicopter designed by him, rising 35 feet and circling a course. This set a record in vertical flight, more than trebling the best previous feat. A few weeks later, in another type of helicopter, the Marquis Pescara accomplished a flight of nearly six minutes. Throughout France helicopter development is receiving the enthusiastic attention of the most eminent aeronautical designers.

In England and Germany, tiny planes analogous to low-priced automobiles enjoy the focus of expert attention.

In the United States, birthplace of the airplane, giant planes, such as the

army's Barling bomber, and great dirigibles, such as the navy's *Shenandoah*, have become the goal of our most distinguished designers.

Among the latest developments in these countries, remarkable are the Halley helicopter in France, shown on the cover of this issue, and the gigantic Followplane aerial cruiser to be constructed in the United States, the design of which is shown in the drawing at the top of these pages.

The new helicopter designed by Charles Halley, a noted French engineer, conceivably may revolutionize aeronautical design. Although this machine exists only as a model, the radical yet apparently sound departures embodied in it have engaged the keen attention of experts everywhere. A successful helicopter would obviate the need for flying fields. Helicopter hangars on office-building roofs would make it possible for business men to commute 100 miles by air and to land the distance of an elevator ride from their offices.

On the Halley machine two bell-shaped wings are attached to a car resembling an airplane fuselage. Two motors in this car drive two propellers revolving in a

vertical plane on each side, drawing air from above the machine and driving it against the curved under surfaces of the wings.

By deflecting the air downward, the wings exert an upward push. Combined with the suction obtained by drawing air from above, this push is said to raise the craft swiftly and vertically.

Tilting the wings ejects the air from the propellers rearward as well as downward. This, the inventor claims, produces sufficient force both to keep the craft aloft and to drive it forward.

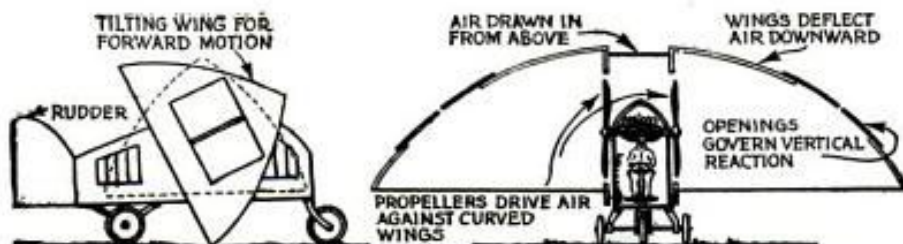
Directed by Controlled Air Currents

In addition to the steering lever, there is a vertical control lever that opens and closes openings in the center of each curved wing. When these holes are opened, part of the air driven against the wings will escape, lessening the vertical propulsion.

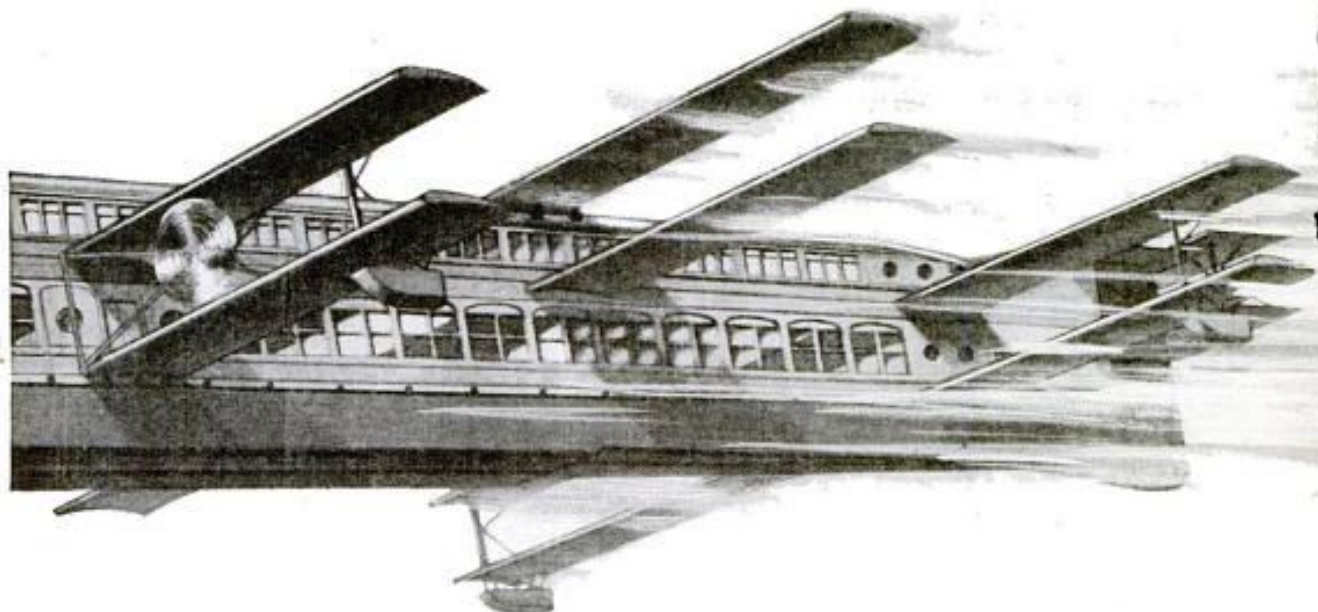
A wider opening is said to cause the machine to hover, practically motionless. And, finally, a still wider opening, the inventor claims, will cause the machine to descend.

It is claimed also that the parachute shape of the wings makes the Halley helicopter comparatively safe, even if the motor should fail.

The huge Followplane air cruiser, designs of which were completed recently by Thomas R. McMechin, once a Zeppelin engineer, and Lt. Arthur Dennison, for-



Diagrammatic views, side and rear, of the revolutionary parachute-like helicopter designed by Charles Halley, French engineer, and pictured on the cover of this issue. Its principle consists of drawing air from above and driving it against the wings to produce upward motion



mer United States Army designer, truly is a remarkable machine.

This gigantic freight and passenger plane, by far the largest ever seriously projected, is to be built at Cleveland, Ohio. It is to be all of metal, 170 feet long, 26 feet from keel to top. It will contain 2500 square feet of floor space and will fly with six staggered pairs of wings, each with a span of 61 feet. Six engines, of 900 horsepower each, will drive six propellers. These engines will be paired, only two operating at the normal cruising speed of 125 miles. The other four will be reserves. It is estimated that a speed of 200 miles an hour could be attained with all six engines operating.

This aerial giant will be a seaplane, capable of rising from and landing on water. The great length of the wings and their staggered arrangement, combined with the weight of the plane, is expected to allow the machine to travel through severe weather with no more than a very slow roll. All combustible supplies will be carried in an airtight compartment, which can be flooded instantly with carbon dioxide in event of fire.

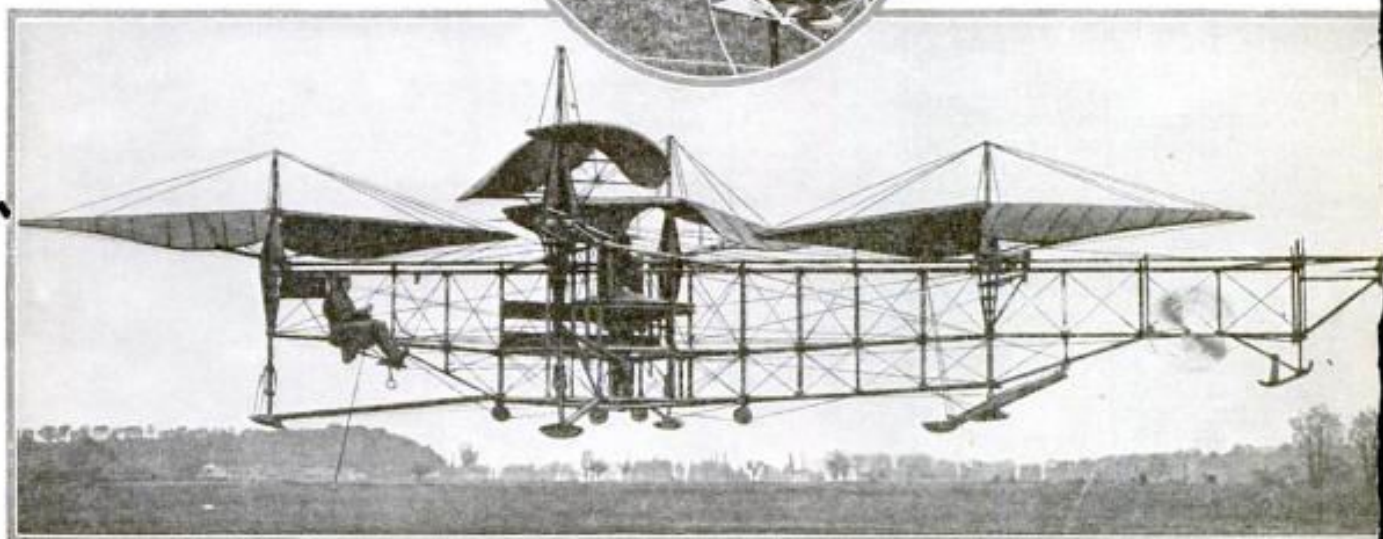
The engines embody numerous radical departures in internal combustion design. They will burn fuel oil, a feature that is expected to reduce their operating cost. It is claimed further that they cannot backfire. Power is transmitted to the propellers through a hydraulic system.

When completed, the great air liner is expected to shorten the traveling dis-

tance from New York to London than 24 hours, at the normal speed of 125 miles. An American man could leave Washington one day and keep a speaking engagement on the next evening. Chicago to New York would be only six hours apart. It is estimated that a \$35 fare would enable the craft to pay a profit on this route. The transatlantic journey, a far more than \$150 would be adequate, it is believed. At least 100 passengers and tons of express freight could be carried.

Staterooms with berths will make night travel feasible, and dining accommodations will be provided. Passengers will not need to remain in seats throughout the journey, as in most passenger planes. Even dancing could be provided, the designers claim. Because of the all-metal construction and fireproof compartments, smoking will be allowed.

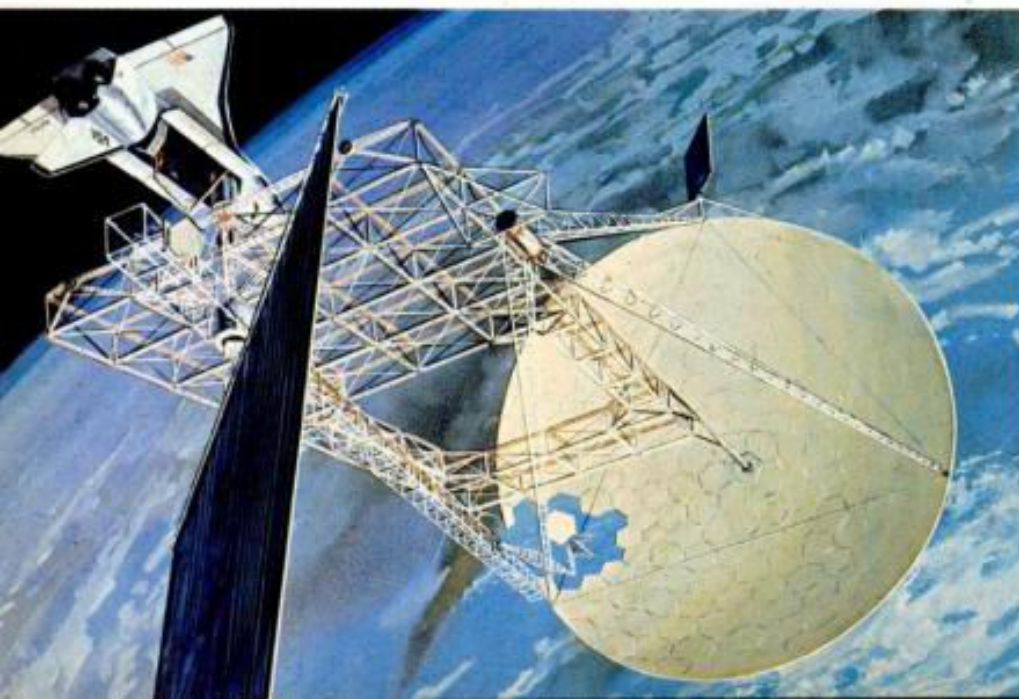
The Halley helicopter and the Fokker plane both represent new mile posts in man's swift conquest of the air. Other aerial models await only the working out of constructional details.



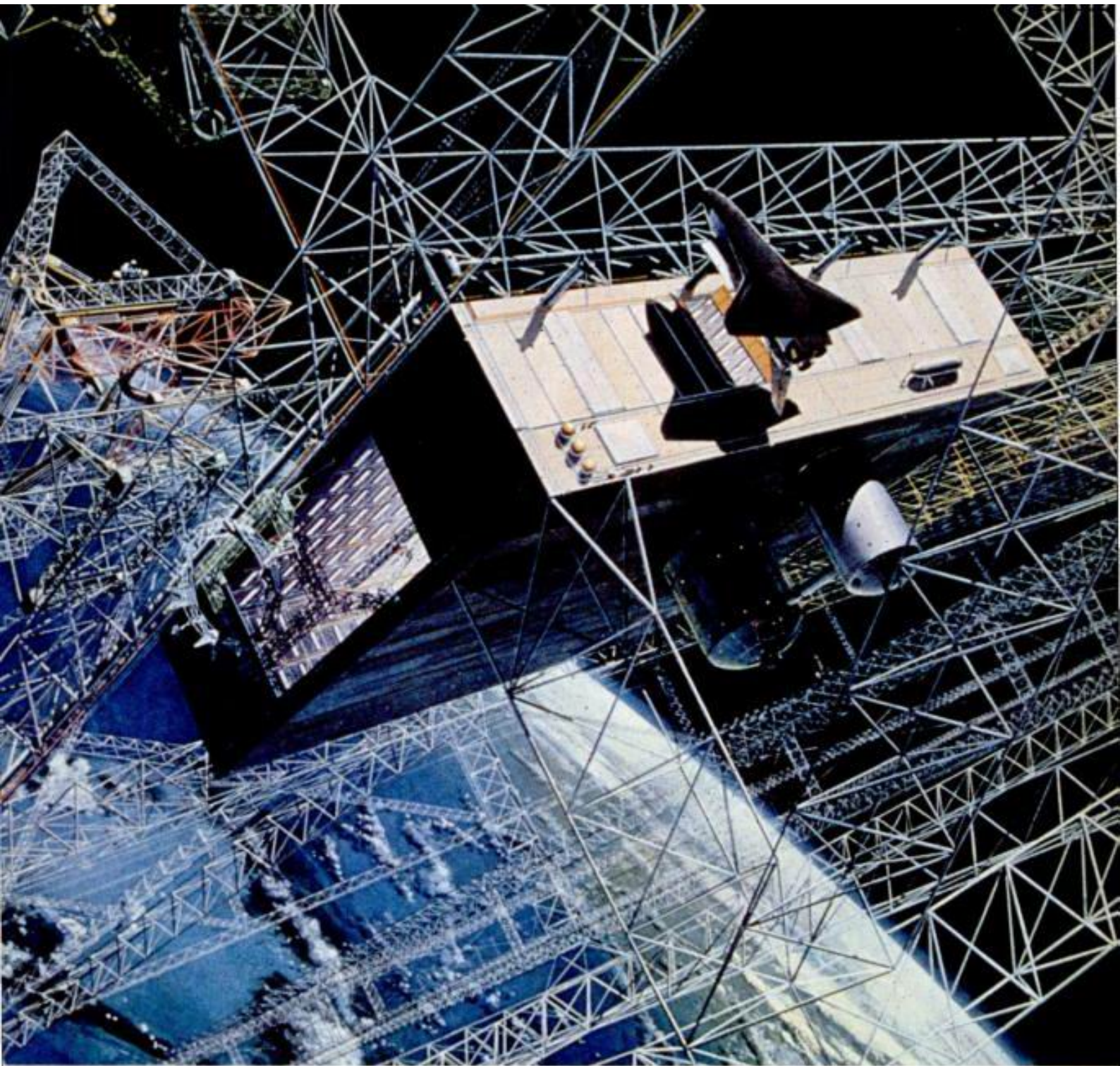
The new helicopter invented and operated by M. Oehmichen, shown in flight during a recent trial near Valentigney, France. The machine rose 35 feet on a circular course, remaining in the air for nine minutes, breaking all previous records for vertical flight. The inset shows the inventor at the controls.

Giant space structures

—how we'll build them



Cigar-shape space station (upper left) has equipment mounted on boom of space beams. Shuttle, docked to orbiting station, has ferried up replacement parts being installed by Grumman's remotely operated cherry picker at end of crane. Practice in such jobs is essential for building orbiting construction shacks (lower left). Here, Shuttle's remote manipulator arm lifts antenna sections onto a trolley that scoots them down to cherry picker for positioning. Large solar arrays power this equipment, which is fashioning the nucleus of a giant solar power station. When completed, miles of weblike trusses (above, right) would be covered with solar cells. In this Boeing version, the framework would be made of thin, telescoping struts brought up in the Shuttle. But both versions would convert solar-generated electricity to microwaves, beaming them—via a giant antenna—to an Earth station for re-conversion to electricity.



An alien environment demands unique building methods and materials

By JIM SCHEFTER

The night view to the south is spectacular. A slightly curved row of bright objects, 45 degrees up from the horizon, rivets the darkness. It looks like a glowing dotted line, waiting for some giant hand to tear open the sky.

Each dot is, in fact, a separate space station or power-generating satellite anchored in orbit 22,300 miles above the equator. So vast is the volume of space that dozens of stations can be set in that line with none affecting any other.

But don't look for that dotted line in the sky just yet. You'll only find it in a few artist's drawings—and in the imaginations of the engineers already at work to make it happen.

Some proposals now being studied involve putting 500 workers into orbit for months at a time to build platforms measured in kilometers. That kind of sky-high thinking—coming at a time when it's still a major chore to put five astronauts into space for a week—makes people shake their heads and wonder what those dreamers will think of next.

But the dreamers have a point. It's hard to fire the imagination of Congress, or of us taxpayers who foot the bill, with glowing descrip-

tions of trusses, beams, joints, and connectors. So the dreamers, practical engineers that they are, talk of mind-boggling satellite solar-power stations as in the painting above.

But they're doing more than dreaming and talking. I've just visited laboratories on both coasts, where NASA contractors are working on volleyball-size joints and beam components you can wrap around your fists. They're developing automatic machines that can spit out beams thousands of feet in length in the weightless conditions of space. They're also designing and testing joints and electrical sockets that will allow the deep-space construction crews to erect

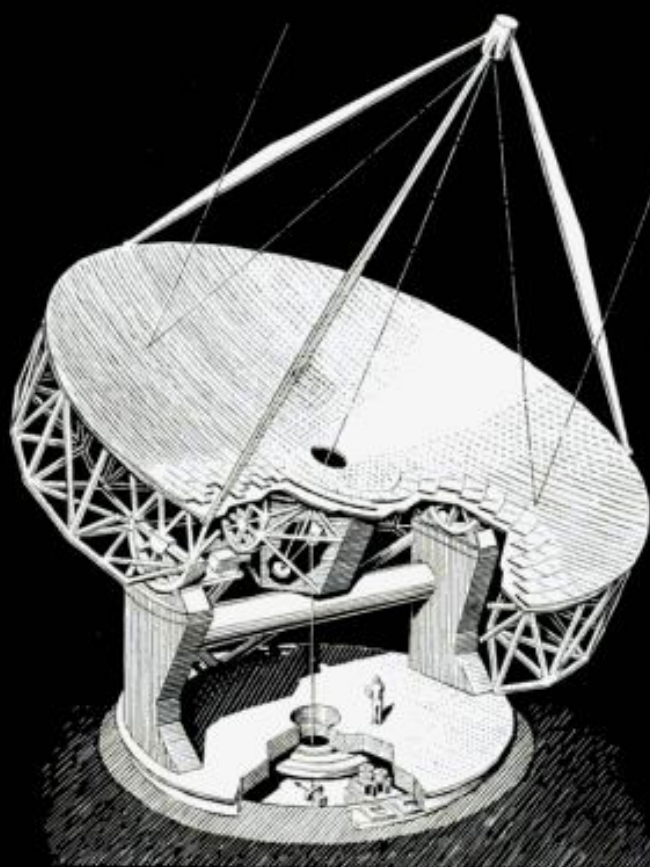
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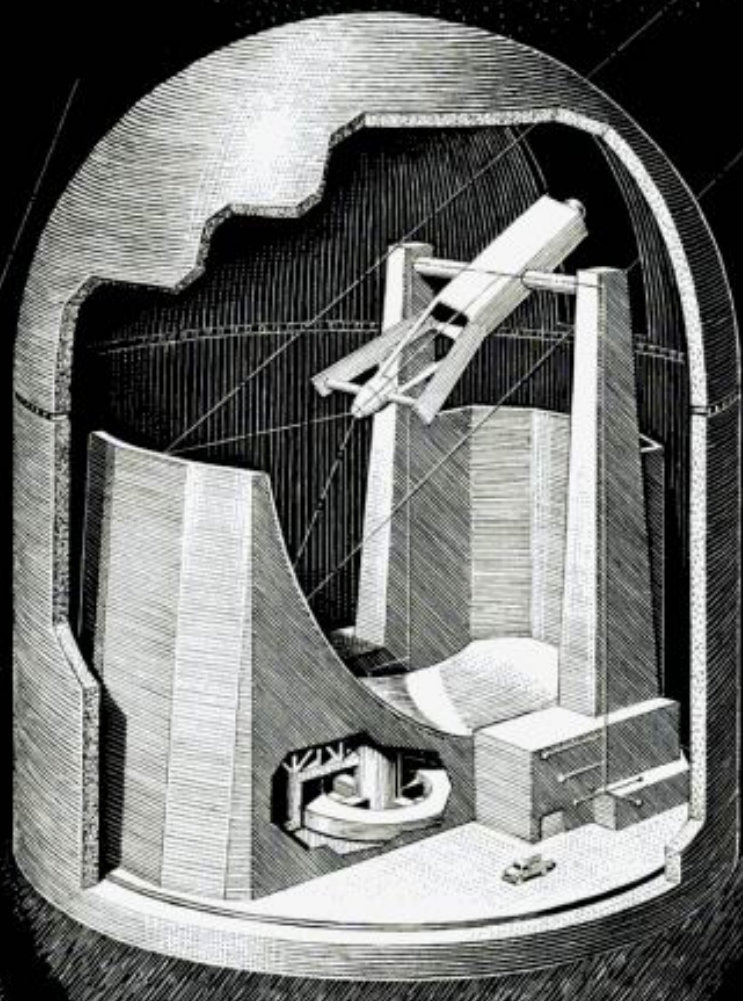
Strut-making in space, the General Dynamics beam-making machine (top, inside NASA canister) extrudes beams made of a graphite-glass laminate. Model of Grumman's working beam former (left) sits upright in Shuttle. Yellow cartridges eject crosspieces for welding to the end caps. These are roll-formed from aluminum strips fed from the white reels.

Giant telescopes

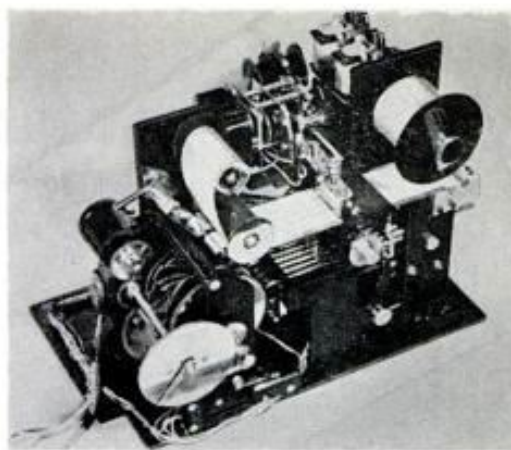
Multiple-mirror instruments will probe the edge of the universe



Steerable-dish concept resembles a giant radio telescope and is the most compact of the four leading designs being considered for a 1000-inch instrument. (A fourth concept is shown in the box on page 77.) Because of the extremely short focal ratio of the dish ($f/0.75$) and other fundamentals of its design, it could actually fit in the dome that houses the 200-inch telescope at Mt. Palomar, even though it has 25 times the light-gathering surface of that instrument. The dish consists of 1032 petal-shaped mirror segments, all forming part of a parabola. Some telescope mirrors have a simpler spherical curve, but the more complex parabola is more common in large instruments. Light gathered by this main mirror is beamed up to a small secondary mirror that reflects it back down through a hole in the center of the main mirror. The light can then be analyzed or photographed. A complex sensing system is required to get the mirror segments working together accurately. Some special problems with this design are solved by a tiny spherical mirror that's put in the center of each parabolic mirror. Laser light reflected from these reference mirrors would be monitored by a computer. Each mirror segment would be attached to a servo motor, and signals sent to these motors from the computer would keep all the mirrors adjusted.



Rotating-shoe concept involves building an 18,800-square-foot primary mirror with hundreds of closely fitting hexagonal mirror segments. This huge primary and its secondary mirror can be rotated as a single element, countering the movement of the Earth. However, the primary doesn't move vertically. Instead, the secondary mirror can be moved independently of the primary. An astronomer aims the secondary mirror at a star by looking at that portion of the primary mirror (approximately one-third) that also sees the star. This portion is equivalent to a single mirror 1000 inches in diameter. Starlight from the primary can be viewed at different locations by the use of other smaller mirrors. To get all of the small mirrors in the primary functioning together requires a central error-control system that regularly scans the 400 to 600 mirror segments being used at any moment. Information relayed to a central processor is used to make fine adjustments in three directions on any mirror segment. Since the mirrors are subjected to varying stresses, the main problem with the design is maintaining the proper curvature for the whole structure to tolerances of a few millionths of an inch. But by keeping the primary fixed in one axis, the shoe concept eliminates some of the changing gravitational stress problems associated with the other designs.



Mechanical Brain Prints Answers in Easy-to-Read Numbers

There are no graphs or punched strips of tape to be interpreted with a new mechanical brain that prints the numerical answers for anybody to read. The machine, called an Analog Data recorder, can record temperature, take weight, measure the length of an object, give the light intensity, voltage, pressure, stress strain and revolutions per minute. It measures and records almost any physical quantity that can be converted into a corresponding voltage. This multiple recorder can be operated re-

motely, printing its data on tape, cards or tickets. Controls can be set for automatic operation, such as the taking of temperature or pressure at specified intervals; or it can be manually operated. The electronic engineers who developed the compact recorder in the laboratories of the Streeter-Amet Company in Chicago report the versatility of the machine is virtually unlimited. It will even do addition, subtraction, multiplication and division by utilizing various components.

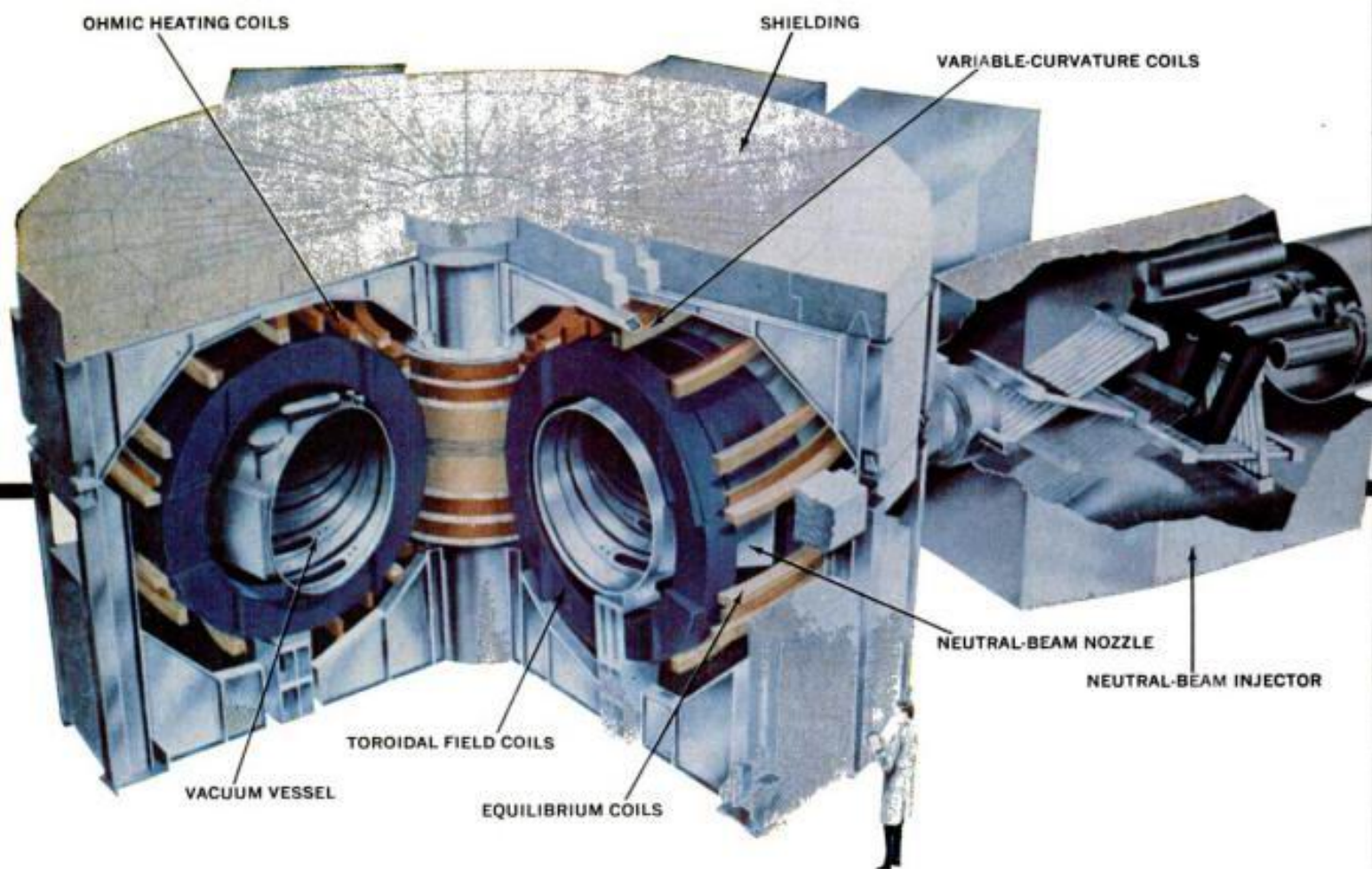
Biggest Transport Helicopter Cruises 150 Miles Per Hour

Weighing 15 tons and believed to be the world's largest transport helicopter, the new Piasecki YH-16 will carry 40 fully equipped troops, 32 litter patients or three

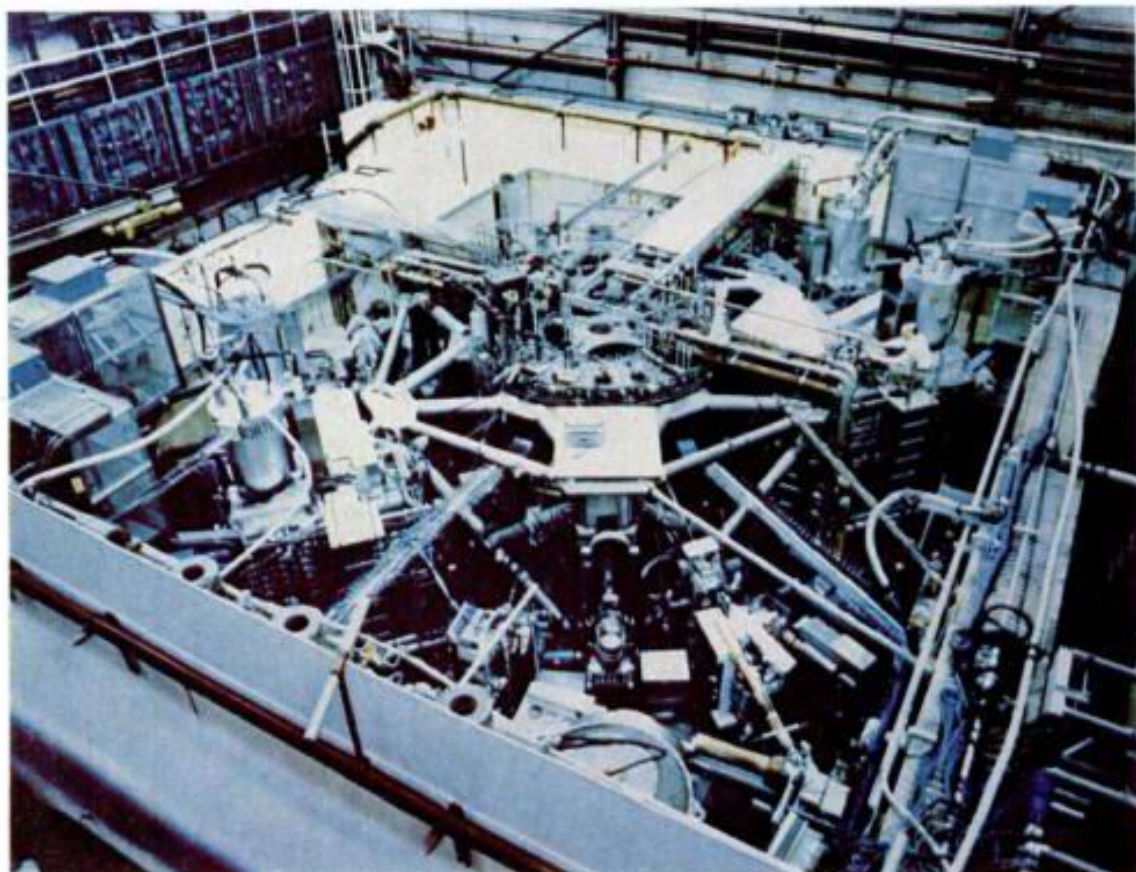
Jeeps. It has a 78-foot fuselage and cruises at nearly 150 miles per hour. Supplies, including guns and ammunition, can be carried in a sling beneath the fuselage.

Dwarfing two other multiplace helicopters, the YH-16's over-all length is 134 feet and its height is 25 feet





Record temperature for doughnut-shape tokamak fusion devices was achieved with the Princeton Large Torus (PLT), right. Equipment creates a magnetic "bottle" to contain a ring of super-hot plasma with a 36-inch cross section. Tokamak Fusion Test Reactor (TFTR), above, being built at the university, will have a plasma 86 inches across. Function of neutral-beam injectors on both devices is to force atoms into the ohmically heated plasma (see text) confined by magnetism from field coils. TFTR should put out more energy that it consumes.





Flexible rafts

harness wave power

By **DAVID SCOTT**
ILLUSTRATION BY DEAN ELLIS

SOUTHAMPTON, ENGLAND

Hinged rafts like the one now bobbing in the waves off the south coast of England could one day provide a major part of this country's electric power, greatly reducing its dependence on fossil fuels.

That's the hope of Sir Christopher Cockerell, noted inventor of the Hovercraft, who hatched the idea of harnessing energy from the sea with articulated pontoons that follow the undulating contours of the surface. He set up a company called Wavepower, Ltd., to exploit the idea, and now the project is one of several parallel ones funded by the British Department of Energy.

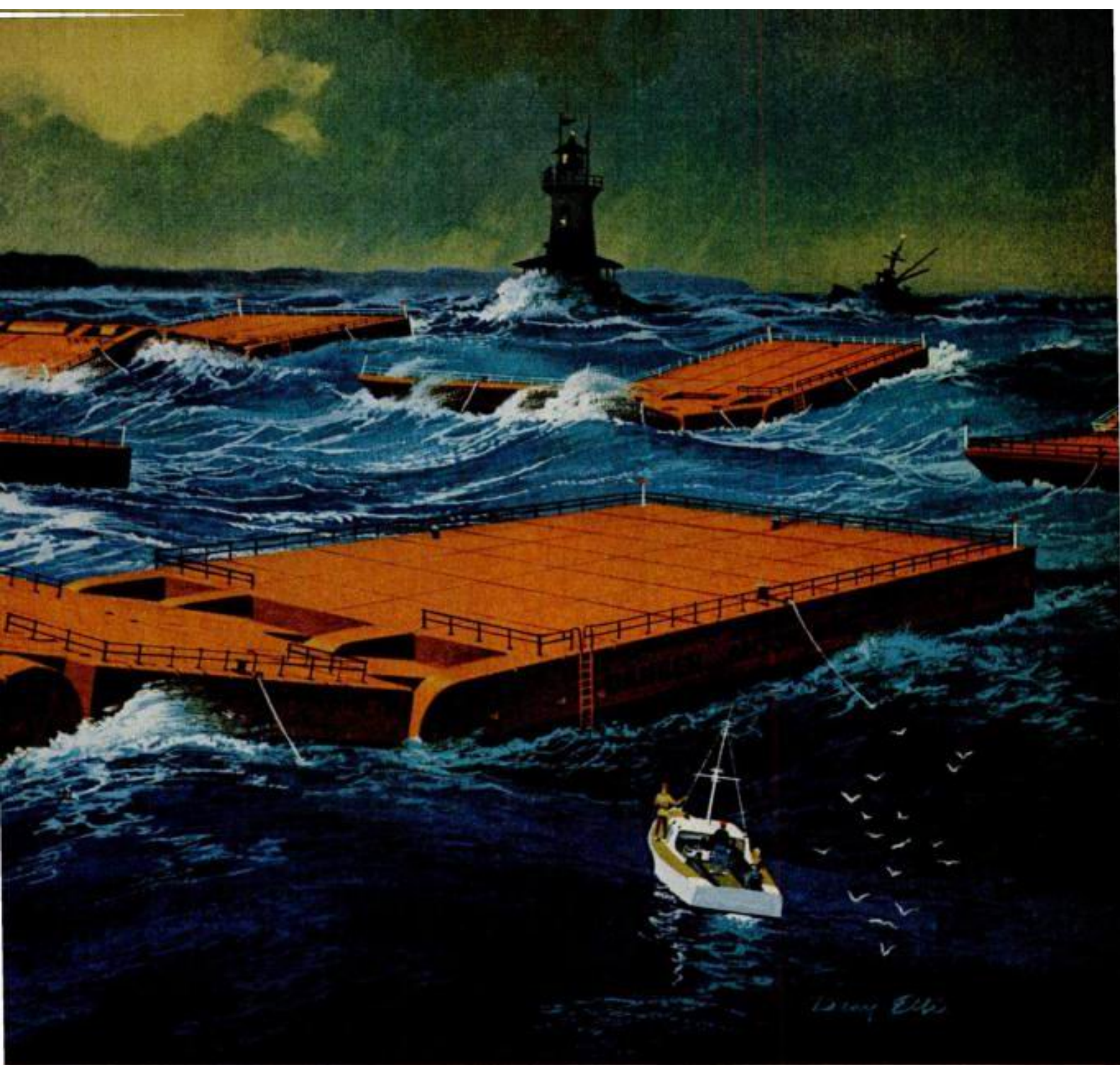
The Cockerell raft is the most advanced of these projects, and the first to have reached the practical-demonstration stage. The trial rig, about 10 yards long and five yards wide, is moored in the Solent, a protected channel between the Isle of Wight and the mainland. It's a one-tenth scale model. That scale was based on the average wave size in these sheltered waters, contrasted with the stormy North Atlantic, where the rafts will ultimately be sited.

The rafts consist of three box-like steel sections with length ratios of 1:1:2, hinged to pivot up and down. As the jointed assembly buckles with the wave crests and troughs, it operates a pair of double-acting hydraulic cylinders,

linked to the outer floats, that work like pumps to power a hydraulic motor driving an alternator.

The average electric output is one kilowatt, though peaks can be much greater. Energy-conversion efficiency is calculated at nearly 50 percent. A hydraulic accumulator between the pumps and motor smooths the delivery for a near-constant pressure—and thus voltage. The generated power is carried ashore by sunken cable.

Looking 10 years ahead, Cockerell sees a string of giant rafts anchored five or 10 miles off the western coast of Scotland. Here lies the richest wave field in the world, where one yard of approaching water has an estimated energy potential of 60 kilowatts. Each raft



would be 10 times the model's size, or 100 by 50 yards. Since energy output multiplies enormously with increasing scale, the power from one rig would be two megawatts.

Meanwhile, the Wavepower team is studying the model's performance and mooring problems in the Solent. An 80-foot barge anchored close by is fitted with com-

plex computer-controlled digital and tape-recording equipment, connected by seabed cable to the heaving raft. Engineers can therefore continuously monitor wave conditions, power output, and strain in critical areas of the device.

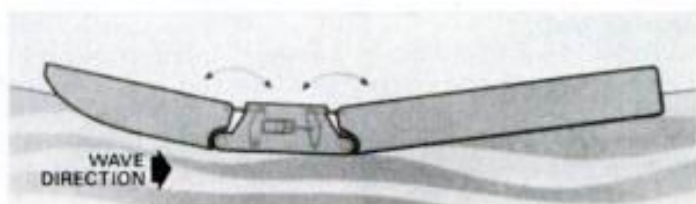
The next step will be to move the model to a nearby open bay where the waves are one-fifth ocean scale.

"There we'd be over-stressing the rig, and getting some idea of its survival capabilities," says project engineer Mike Urwin.

It's still a long haul ahead to serious power generation from this form of renewable energy. But for the British Isles, with extremely long coastlines, the effort could pay off handsomely. **ES**



Experimental model of Wavepower raft, about 30 feet long, bends in swells of the Solent near Southampton, England. Three-section hinged raft is anchored by mooring lines.



As raft flexes with waves, hinged outer floats operate double-acting hydraulic cylinders in central section. Cylinders pump fluid to hydraulic motor driving an alternator.



Tall, stubby, SPS vehicle is steam-powered, gets 12 mpg in city driving, burns almost any fuel. Top speed: 66 mph.

Alfa's new taxi is aimed at the European market, but meets the specs for MOMA's project. Rubber belt protects body.



AMF's entry has Jay Carter steam engine familiar to PS readers, electric door, unitized steel-and-aluminum frame.



Volvo uses diesel engine, has maximum speed of 85 mph. DeDion rear axle provides comfortable ride. Abundant luggage space is convenient for the passenger who wants to serve himself.

JANUARY 1977 75 CENTS

Popular Science

The **What's New** magazine

**FORD'S
2-IN-1 ENGINE**
—sometimes it's a six,
sometimes it's a three

TORNADO TURBINE

reaps power from
a whirlwind

PSB SCANNERS
—radios that
keep you tuned
to the action

SPACE SHUTTLE
gets ready to fly

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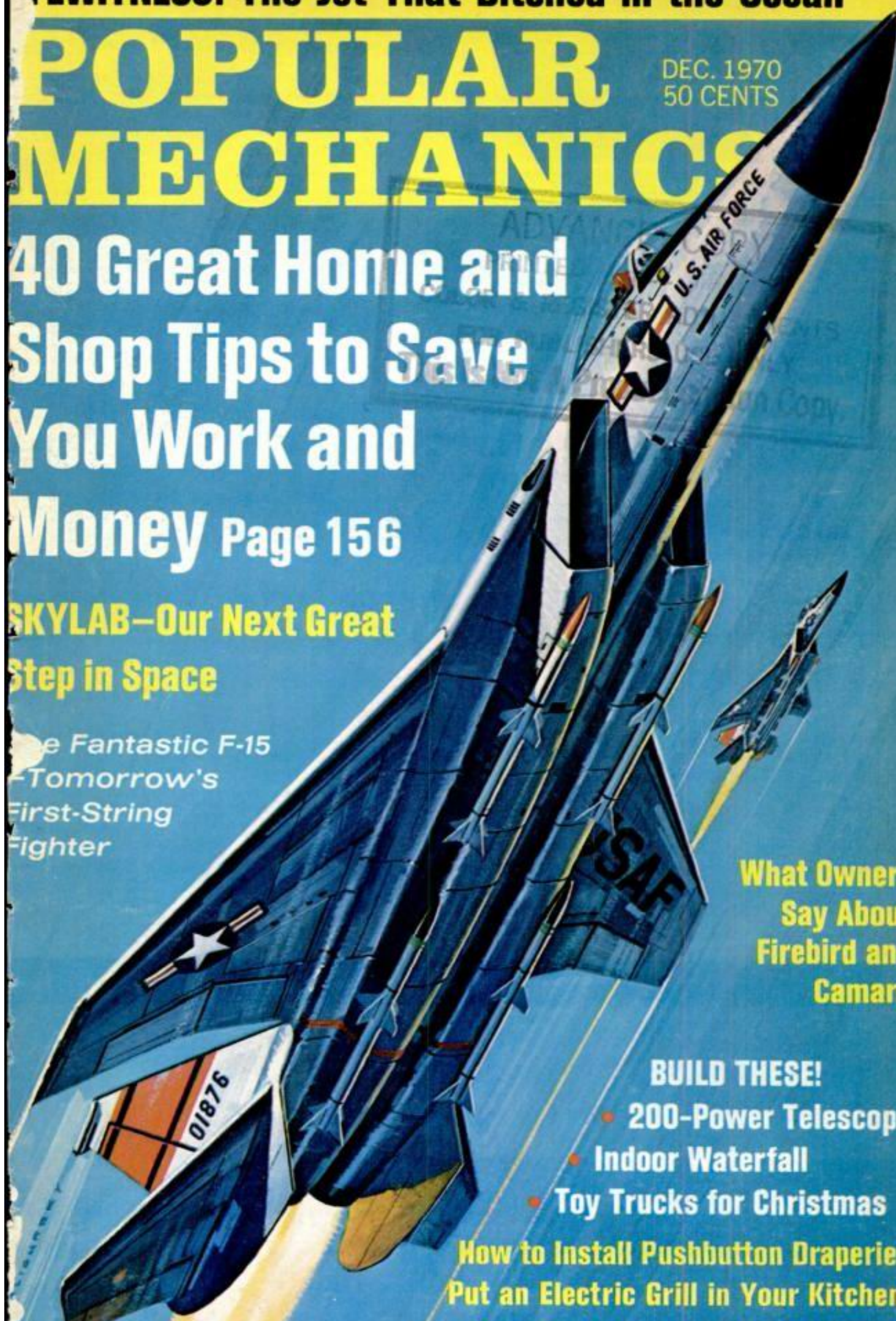
**The Fantastic F-15
—Tomorrow's
First-String
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**What Owners
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BUILD THESE!

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Put an Electric Grill in Your Kitchen!**



AVIATION



A FIGHTER PILOT'S FIGHTER PLANE

Though it can do many things, the Air Force's F-15 is a plane with a single purpose—to tangle with enemy fighters and destroy them.

By KEVIN BROWN

IN WORLD WAR II, American fighter pilots racked up a record of eight victories for every loss. In Korea, the kill ratio soared to 14-to-1. In Vietnam, with only sporadic activity by enemy aircraft, the ratio dropped to a near standoff 2-to-1.

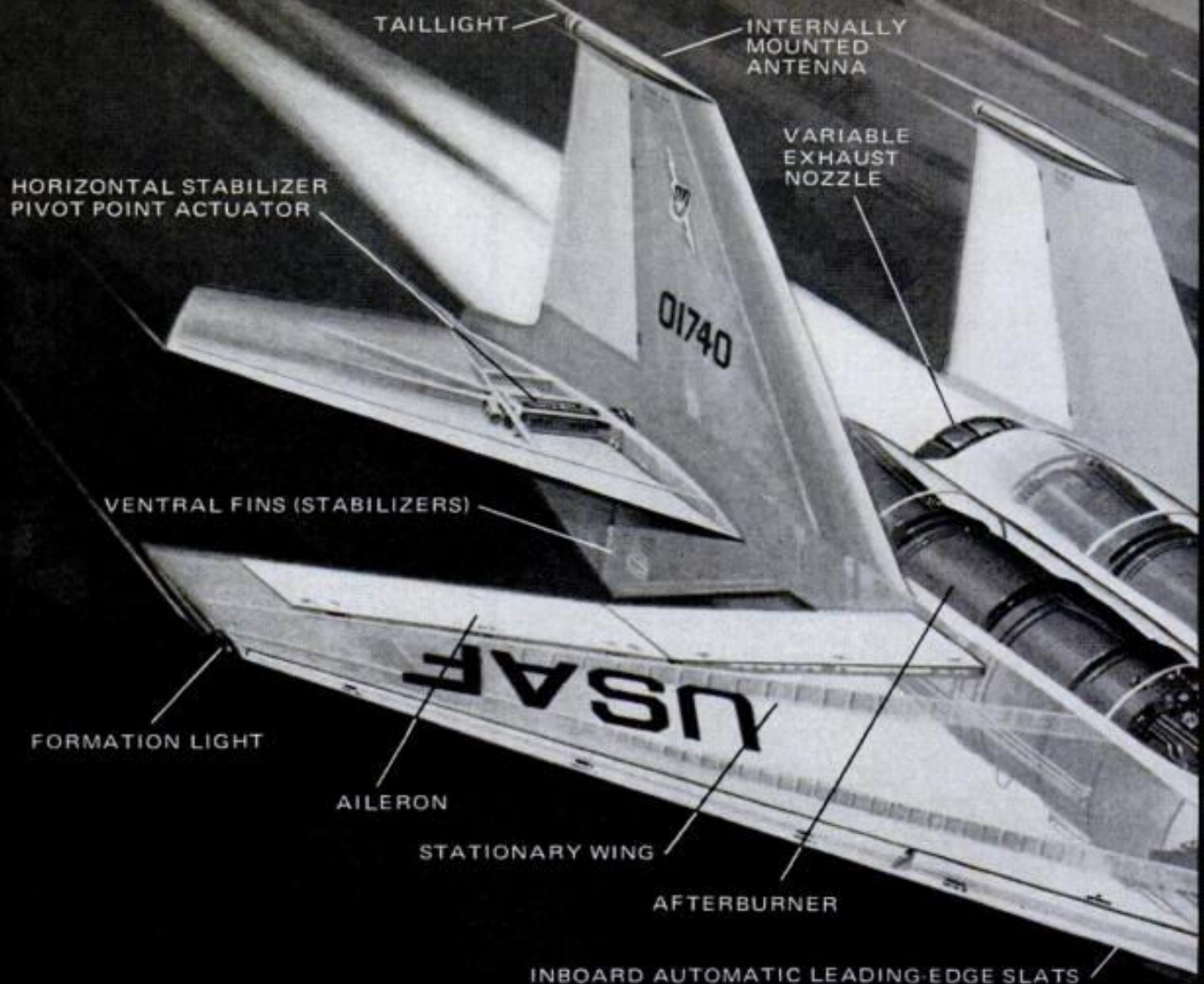
What happened?

American fighter pilots are still as good as ever, perhaps the best in the world. And, in Vietnam, they were flying against second-rate pilots in not quite first-rate aircraft—hand-me-down Russian MiGs. Still they could do no better than score two victories for every loss. The men in the Pentagon who worry about such things decided it was not the pilots but the planes.

The best American fighter in Southeast Asia was the F-4 Phantom II. But its history goes back as far as 1954, and its improvements have reached a saturation point. Others used extensively in Vietnam, the F-100 Supersabre and F-105 Thunderchief, go back even farther.

Worse, the Russians weren't standing still in technological development. The MiGs they sent to the North Vietnamese, even though they just about held their own, were not the best in their inventory. At a recent Moscow air show, the Soviets showed no less than six new fighters, several of which had characteristics superior to anything we now have flying, specifically more maneuverability and better acceleration. And we have nothing new coming along to top them.

Until now. The Navy is working on a new fighter to guard its fleet called the F-14 (See *A Hot New Fighter for the Navy*, page 83, Jan. '70 PM.) And just recently the Air Force announced the awarding of contracts to build a new



fighter called the F-15 to clear the skies over land.

This is the story of the F-15, and, in an era when the cost-conscious people who make these decisions require every new aircraft to be all things to all men, it is something unique. The F-15 is the first fighter in 20 years to be designed for only one mission—fighting other fighters. Whatever other duties it may perform—reconnaissance, air-to-ground attack—will be entirely secondary, with no compromise in the hardware to fit it for these roles. The last fighter to be so privileged was the F-86 Sabrejet, which built up an unbelievable record in Korea. The decisionmakers were reminded of this when making their decision.

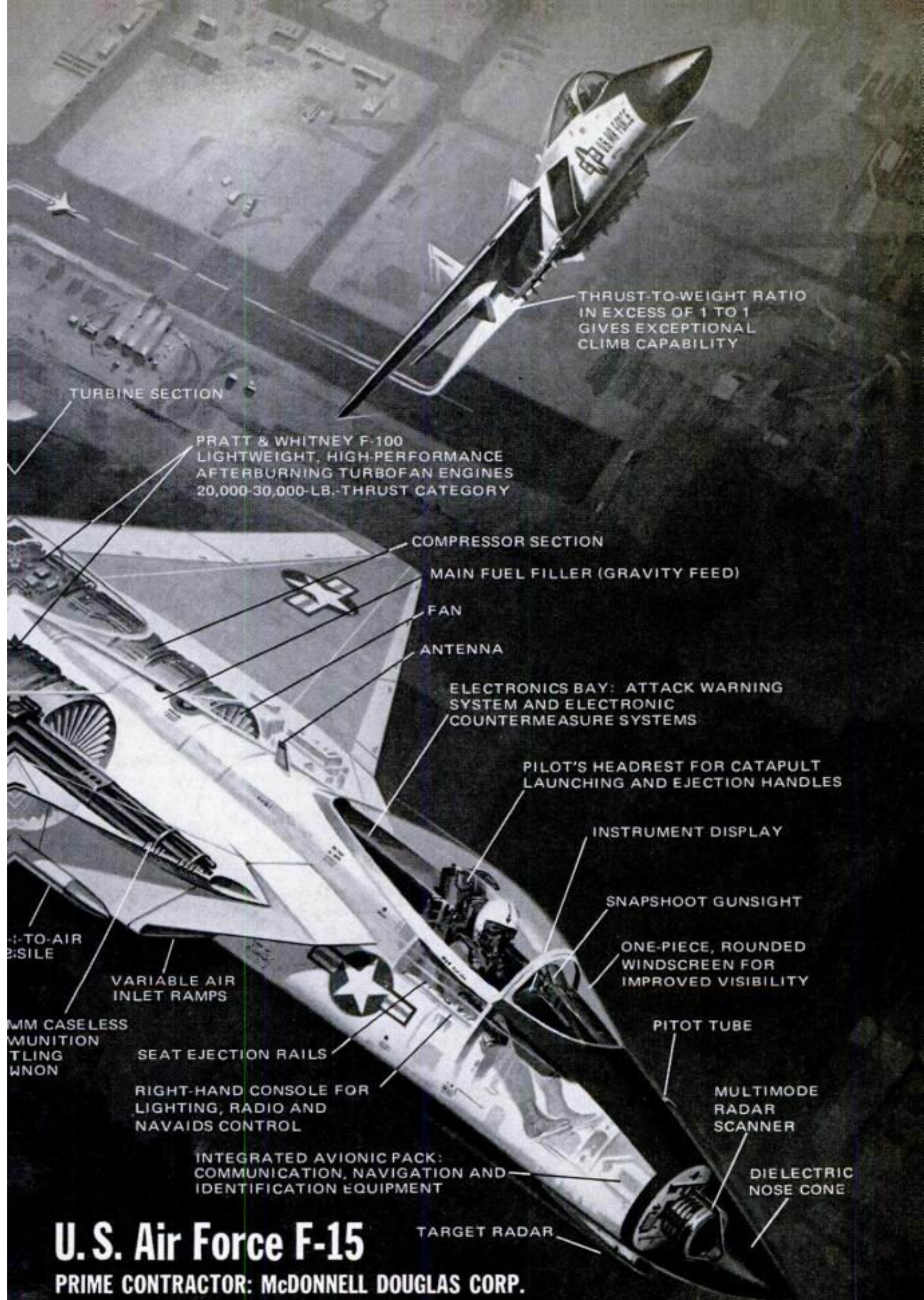
So, in Air Force language, the F-15 is meant to "find, identify, engage and destroy enemy aircraft."

In layman's language this means, "Go

get 'em, make sure they're the bad guys, then stick the gun up their tailpipe and pull the trigger!"

To perform this simple mission the F-15 needed a simple design. Advocates of using new technology to build airplanes bigger and more powerful to fly higher and faster are often surprised to learn that the recent history of aerial combat destroys this myth. Most dogfights these days are done at subsonic speeds and at low altitudes. The highest engagement speed on record is Mach 1.3, and the normal combat altitude is around 10,000 feet, and below Mach 1. So high mach numbers and high-altitude capabilities are irrelevant in the heat of combat, which is the ultimate purpose of a fighter.

What is relevant is range enough to go where the enemy is, maximum maneuverability to outfly him when you get



THRUST-TO-WEIGHT RATIO
IN EXCESS OF 1 TO 1
GIVES EXCEPTIONAL
CLIMB CAPABILITY

TURBINE SECTION

PRATT & WHITNEY F-100
LIGHTWEIGHT, HIGH-PERFORMANCE
AFTERBURNING TURBOFAN ENGINES
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MAIN FUEL FILLER (GRAVITY FEED)

FAN

ANTENNA

ELECTRONICS BAY: ATTACK WARNING
SYSTEM AND ELECTRONIC
COUNTERMEASURE SYSTEMS

PILOT'S HEADREST FOR CATAPULT
LAUNCHING AND EJECTION HANDLES

INSTRUMENT DISPLAY

SNAPSHOT GUNSIGHT

ONE-PIECE, ROUNDED
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IMPROVED VISIBILITY

PITOT TUBE

MULTIMODE
RADAR
SCANNER

DIELECTRIC
NOSE CONE

TARGET RADAR

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INLET RAMPS

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RIGHT-HAND CONSOLE FOR
LIGHTING, RADIO AND
NAVAIDS CONTROL

INTEGRATED AVIONIC PACK:
COMMUNICATION, NAVIGATION AND
IDENTIFICATION EQUIPMENT

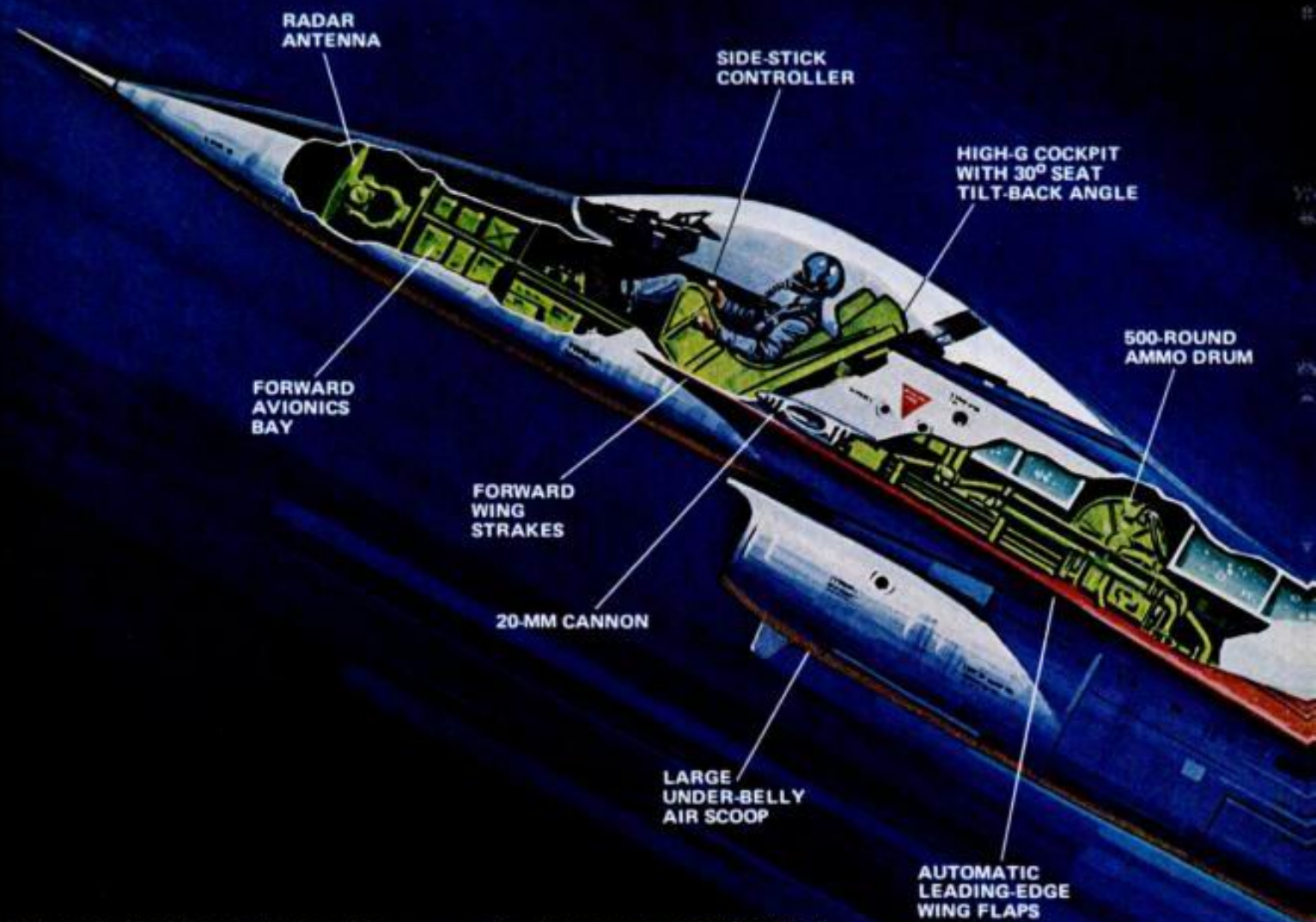
AIR-TO-AIR
MISSILE

30-MM CASELESS
MUNITION
STOWING
BIN

U.S. Air Force F-15

PRIME CONTRACTOR: McDONNELL DOUGLAS CORP.

Illustration by Roy Grinnell and Fred Wolff



Never before has a single military aircraft excited so much interest the world over. It's the F-16, newest, hottest addition to U.S. air might and a plane that may well become the most sought after of all time. Scarcely off the drawing board, the fighter has not only been adopted by our own Air Force, but has become the popular choice of four other NATO nations, beating out such stiff competition as the famous French Mirage and the radically new canard-winged Swedish Viggen.

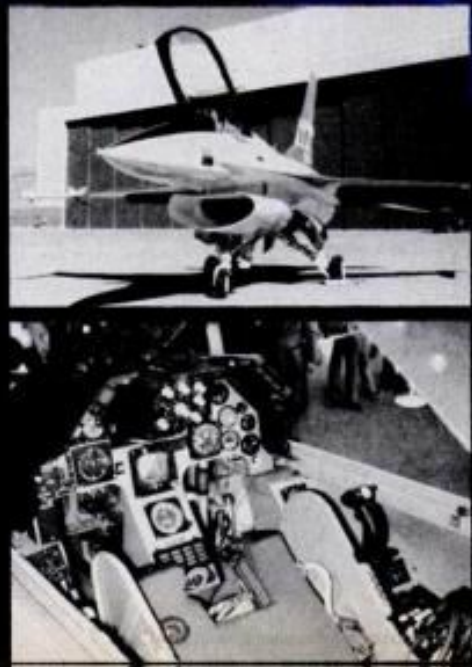
Belgium, Norway, Denmark and the Netherlands have jointly signed up to purchase 350 of the sleek, multi-role supersonic jets, and other countries, including Canada, may follow suit. The U.S. Air Force has ordered 650, and the Navy is expected to buy 800 more for carrier use, bringing the initial total to 1800. With anticipated additional purchases, production runs may eventually go as high as 3000 to 4000—possibly the greatest number of any

one aircraft type ever manufactured.

What accounts for the F-16's incredible appeal? It's not the biggest, not the fastest, not the most powerful. In fact, by modern fighter standards, it's a relative baby. Developed by General Dynamics, the single-engine single-seater represents a new concept in low-cost, high-performance lightweight fighters, designed to provide both air superiority and economy at the same time. It's fast, tough, deadly and versatile—all for what is considered the remarkable price of \$4.6 million per plane. That may not sound "cheap" to those of us who cringe at a \$50 grocery bill, but in the world of military hardware it's a bargain—other comparable fighters go for \$8 to \$12 million apiece.

With an overall length of 47½ feet and a wingspan of 31, the F-16 is considerably smaller than earlier fighters like the F-14 Grumman Tomcat (62 by 64 feet) and the F-15 McDonnell Douglas Eagle (64 by 43

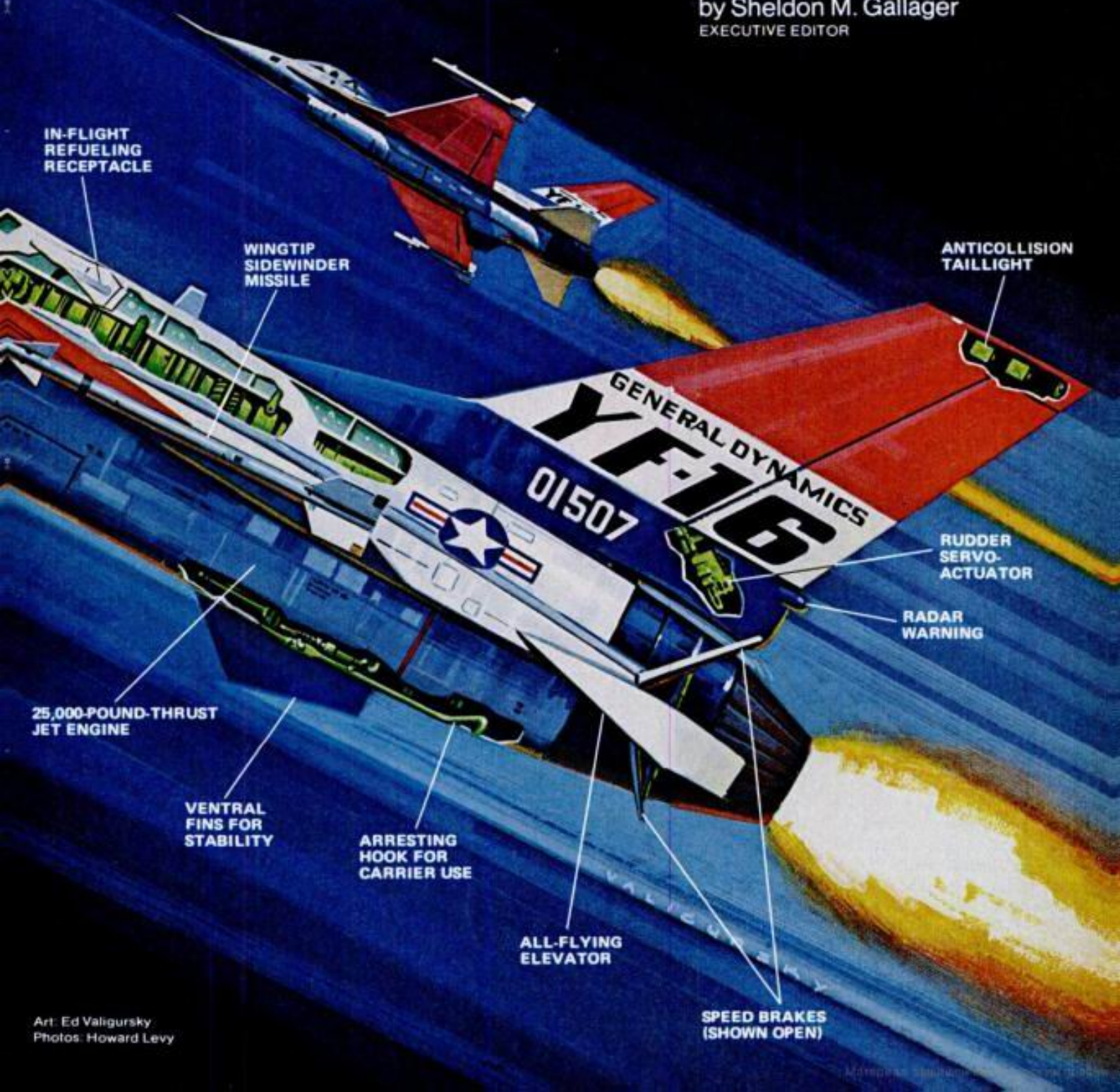
Needle-nosed F-16 is small, light, highly maneuverable fighter capable of Mach 2 speeds (twice the speed of sound). Below, note side-stick control handle on right and sharply back-tilted seat to help the pilot withstand high G forces in combat.



(Please turn to page 124)

F-16 The fighter everybody wants

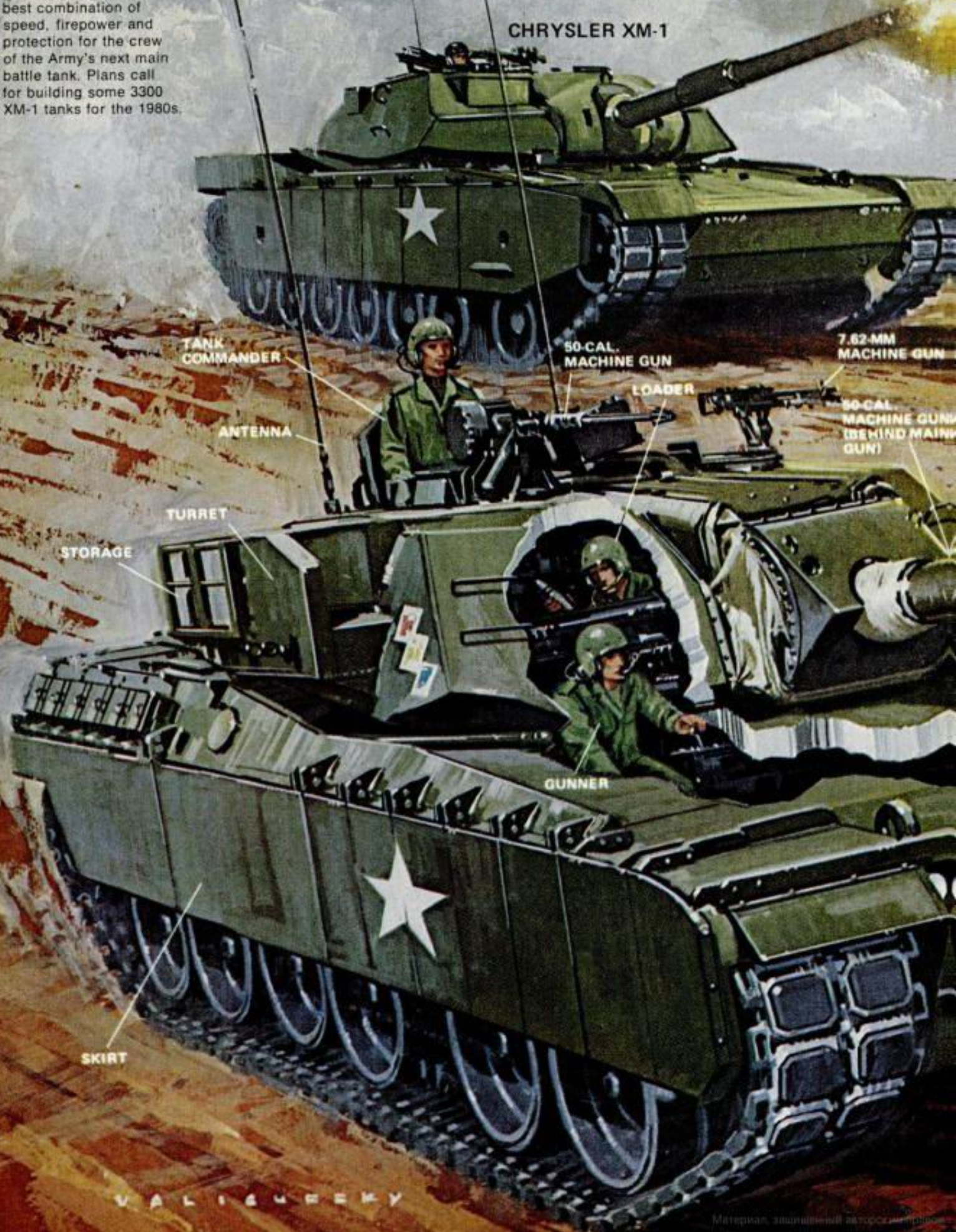
by Sheldon M. Gallagher
EXECUTIVE EDITOR



Art: Ed Valigursky
Photos: Howard Levy

The Army's tough testing program involves the three prototypes shown: the General Motors XM-1, the Chrysler XM-1 and the West German Leopard II. The goal: to settle on the best combination of speed, firepower and protection for the crew of the Army's next main battle tank. Plans call for building some 3300 XM-1 tanks for the 1980s.

CHRYSLER XM-1



TANK
COMMANDER

ANTENNA

50-CAL.
MACHINE GUN

LOADER

7.62-MM
MACHINE GUN

50-CAL.
MACHINE GUN
(BEHIND MAIN
GUN)

TURRET

STORAGE

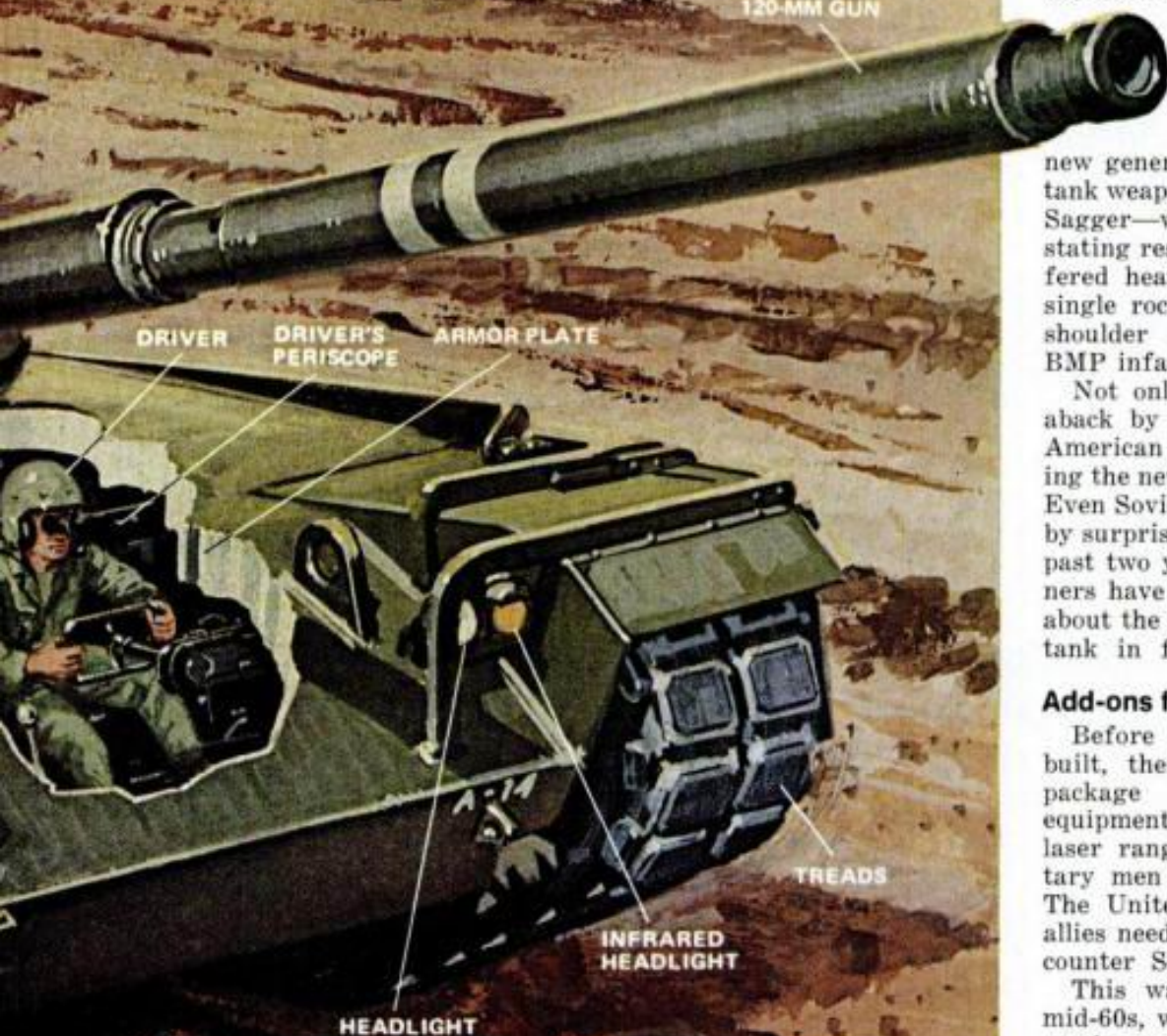
GUNNER

SKIRT



LEOPARD II

105-MM OR
120-MM GUN



DRIVER

DRIVER'S
PERISCOPE

ARMOR PLATE

TREADS

INFRARED
HEADLIGHT

HEADLIGHT

GENERAL MOTORS XM-1

stake in the United States is a \$4.9-billion contract for 3325 of the new tanks, which Army officials claim are desperately needed to replace the 17-year-old M-60 series and the 24-year-old M-48.

The XM-1 main battle tank, to be named the "Abrams" after the late Gen. Creighton Abrams, Army Chief of Staff at his death and a highly decorated World War II battalion tank commander, also is in contention for what some armaments salesmen are calling "the contract of the century." What excites them is the possible standardization of all NATO forces and the adoption of the same weapons, ammunition and equipment, including some 10,000 main battle tanks. An estimated \$12 billion will be spent on tanks by the NATO powers during a 15-year period starting in 1979.

At the same time, the battle tank has become a highly controversial weapon. Some critics in Congress claim that the tank is as obsolete as the battleship. They cite the disastrous experience suffered by Israel during the first days of the October 1973 war in the Middle East when a new generation of Soviet-built anti-tank weapons—Snapper, Swatter and Sagger—were employed with devastating results. Israel tank units suffered heavy losses, especially from single rocket rounds fired from the shoulder or from the Soviet-built BMP infantry combat vehicle.

Not only were the Israelis taken aback by their losses, but so were American military officials monitoring the new Soviet antitank weapons. Even Soviet military men were taken by surprise—so much so that for the past two years Soviet military planners have been engaged in a debate about the effectiveness of the battle tank in future combat operations.

Add-ons for the M-60

Before the XM-1 prototype was built, the U.S. Army developed a package of sophisticated add-on equipment for the M-60, including a laser rangefinder. But to our military men this was only a stopgap. The United States and her NATO allies needed a more modern tank to counter Soviet armored might.

This was the view even in the mid-60s, when the U.S. and German armies worked together to develop the MBT-70—a billion-dollar flop. Military officials of both nations couldn't agree on what should go into this new tank and so each country went its own way. The United States

(Please turn to page 140)



World's longest 'people' tunnel

It will have taken more than 35 years to build, but when Japan's 33-mile-long undersea railway is finished it will represent one of the most ambitious and adventurous engineering feats ever.

by L. Donald Meyers

According to the *Guinness Book of World Records*, the world's longest tunnel is the 85-mile Delaware Aqueduct running from tributaries of the Delaware River to New York City. But it carries water, not people. Japan is building a high-speed railroad tunnel that will far outdistance any "people" tunnel in existence. It will stretch 33.6 miles underground—14.5 of these under water—will encounter some of the most treacherous terrain any tun-

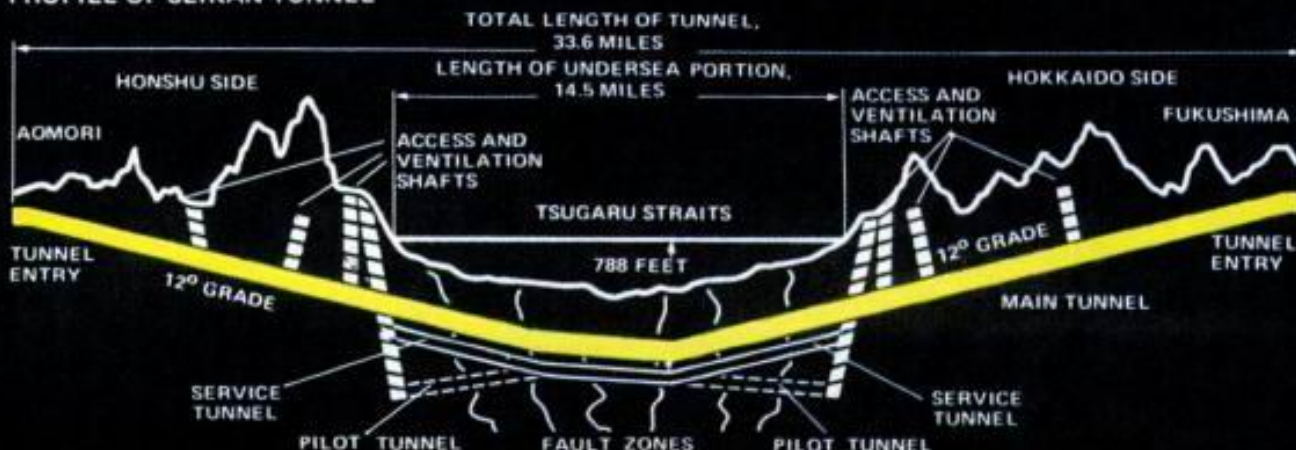
nel has had to face, and will represent one of the mightiest, costliest, most complicated engineering feats ever undertaken.

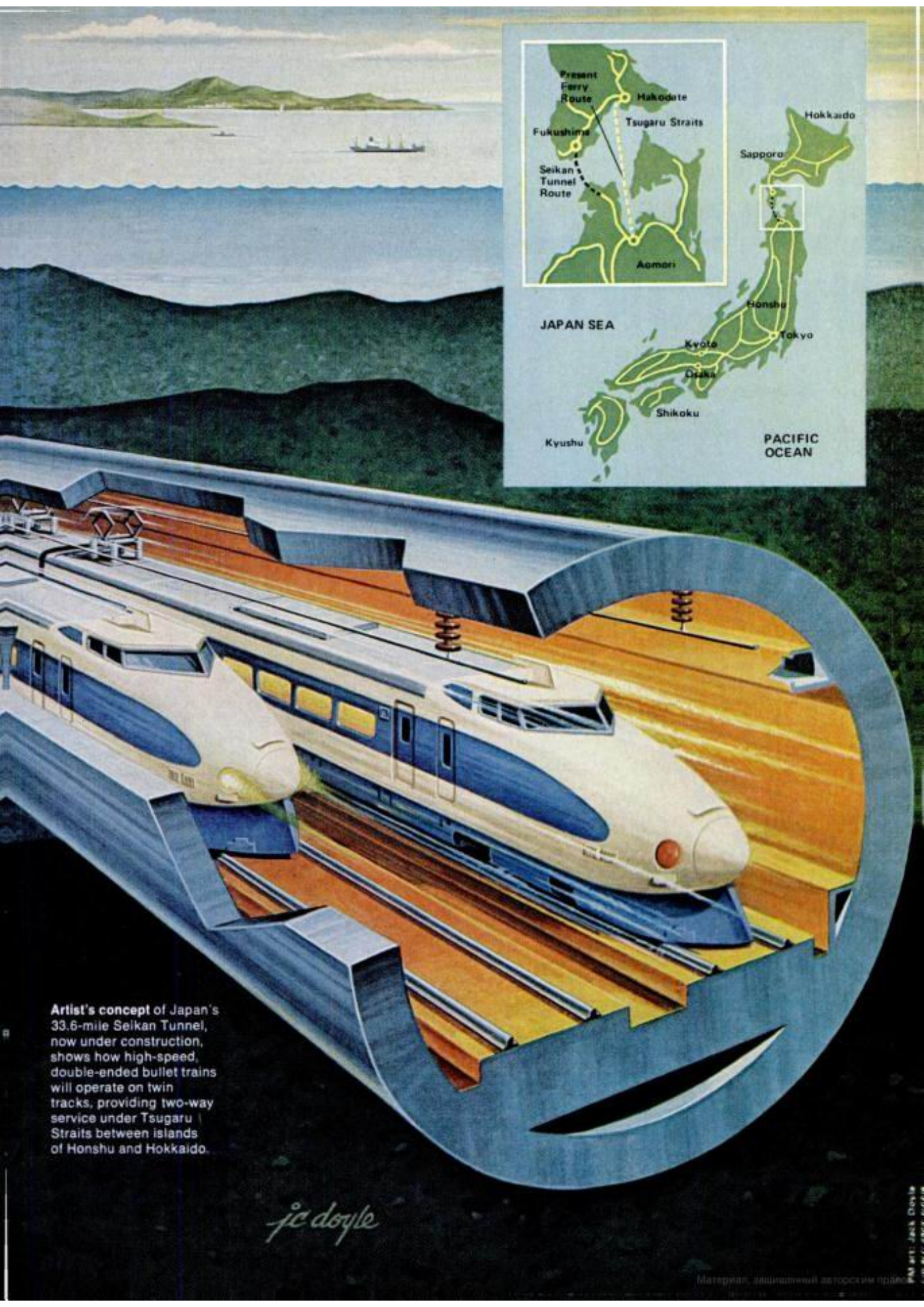
Called the Seikan Tunnel, it will fulfill a long-held dream of the Japanese people to be able to travel anywhere in their chain of four major islands by train. The largest, most populous of these islands is Honshu—the long, curving strip that forms the "body" of Japan's familiar dragon shape where

the biggest and best-known cities of Tokyo, Osaka and Kyoto are located. The dragon's "feet"—Kyushu and Shikoku—are already, or soon will be, linked by rail to Honshu. Only the dragon's "head"—Hokkaido—remains isolated. There are limited air and ferry services between the two, but the severe and frequent storms that rage in the Tsugaru Straits make such over-water crossings uncertain and often

(Please turn to page 162)

PROFILE OF SEIKAN TUNNEL





JAPAN SEA

PACIFIC OCEAN

Artist's concept of Japan's 33.6-mile Seikan Tunnel, now under construction, shows how high-speed, double-ended bullet trains will operate on twin tracks, providing two-way service under Tsugaru Straits between islands of Honshu and Hokkaido.

jc doyle



Massive Aquapolis, shown under construction in Hiroshima, provides ample room for 2400 visitors and a crew of 195. Its cost will top \$35 million.

Aquapolis: City in the sea

by Bob Berger

That iron monster of the sea, the semisubmersible drilling rig, has come into its own as the search for offshore oil intensifies in many corners of the world. A number of nations build the huge platforms, but Japan is the first to use the basic design to create something that is completely different—a floating tourist attraction.

Called "Aquapolis," the semisubmersible will be the Japanese government's star attraction at International Ocean Expo '75, an exhibition devoted to increasing our awareness of the ocean's importance to life. Japanese officials regard Aquapolis as a prototype of the self-contained marine community of the future.

Site of the exposition will be the island of Okinawa, a subtropical spit of land familiar to some veterans of World War II. Expo will run from July, 1975, to January, 1976.

Like its drilling-rig cousins, Aqua-

polis is big. It displaces 28,000 tons and its upper deck contains over 100,000 square feet of space—room enough for a heliport, and trees and park benches for the weary of foot. The main deck contains the central hall, reputedly the largest single room ever to put to sea.

Visitors ride escalators through some exhibits. One feature of the "sea forest" display is a tank holding billions of one-celled organisms called chlorella, which give off a green glow. They also have the peculiar ability to manufacture fresh water, a talent used as part of the project's life-support system.

At this writing, finishing touches are being put on Aquapolis at a Hiroshima shipyard. From there, it will be towed some 600 miles south to Okinawa and moored off the Motobu Peninsula. A bridge will link the floating island with the onshore segments of Expo '75.

★ ★ ★



Huge ballasted hulls, which may ride some 60 feet under water, provide great stability for the structure. Artist's concept shows how Aquapolis will be moored off one of Okinawa's beaches.

Rescue in space

A new era in space travel in the 1980s will see the Shuttle making weekly trips into Earth orbit. For an extra margin of safety, NASA is developing rescue systems for marooned or injured astronauts.

by John F. Pearson

SCIENCE EDITOR

Hey, we've got a problem here." It was this laconic report from the crew of Apollo 13 to Mission Control in Houston that served to let the world know that the flight was in trouble. Some 200,000 miles from Earth as it hurtled toward the moon, Apollo 13 had been crippled by the explosion of a liquid-oxygen tank in the big service module.

The three astronauts suddenly were faced with a grim possibility: They could become the first men stranded in space. That they ultimately avoided this fate was a tribute to their own coolness and training, and to the engineering know-how available to them via radio from Houston.

As a waiting world was to learn,



The "ball" astronaut carries is a "personal rescue enclosure" now under development at NASA's Johnson Space Center, Houston. It's big enough to contain a person sitting with knees pulled up and has its own life-support system. The spacesuit, also new, is lighter, less bulky than Apollo suit. Below: Rescue Orbiter glides to a landing at Florida or California base.



smooth coordination between the astronauts and Mission Control solved the problem. Using power and life-support systems of the lunar module (intended for the moon landing), Apollo 13 swung around the moon and returned to the vicinity of the Earth. On Apr. 17, 1970, the command module carrying Jim Lovell, Tom Mattingly and Fred Haise made a safe re-entry.

In Houston, relief was mixed with the knowledge that a grim lesson had been learned. Robert R. Gilruth, then director of the Space Center, put it this way: "I think it has been made quite clear, more than by any of the Apollo flights up to this point, that flying to the moon is not just a bus ride."

No flight into space is "just a bus ride." An astronaut stranded in a crippled craft only 200 miles from Earth is as vulnerable as if he were adrift 200,000 miles away. In time he will fall victim to the same deadly environment; in time his life-sustaining oxygen will give out. The big difference is he is in Earth orbit, close enough to be helped by a quickly mounted rescue effort.

When NASA's Space Shuttle program is in full swing in the 1980s, there will be a flight a week into Earth orbit. More flights mean more chances that something may go wrong. It is not surprising, then, that NASA is now working on a rescue system for this program.

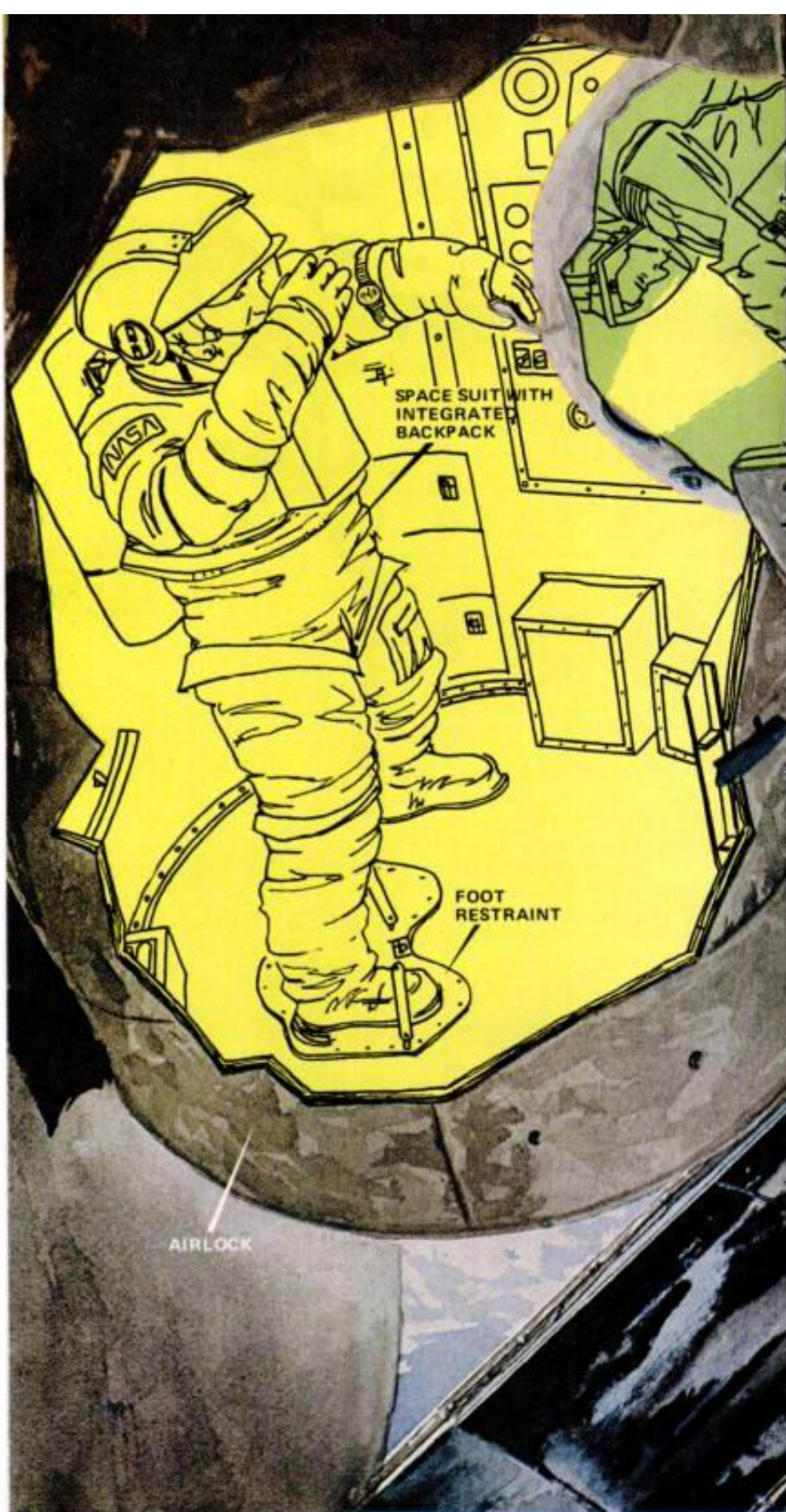
The Shuttle project is built around the Orbiter, a delta-winged craft about the size of a DC-9 that is a combination space vehicle and airplane. By the time this article appears, the first Orbiter will have been rolled out of a California factory. An extensive test program will lead up to an initial orbital flight in 1979. If all goes well, as many as five Orbiters will be in operation in the 1980s.

How Shuttle will work

Here, in brief, is how the Shuttle will work: In addition to three big rocket engines in the Orbiter's tail, two solid rocket boosters will be used to get the vehicle into orbit. At an altitude of 25 miles, the boosters will be jettisoned and descend by parachute for ocean recovery. Like the Orbiter, the boosters will be used for many flights.

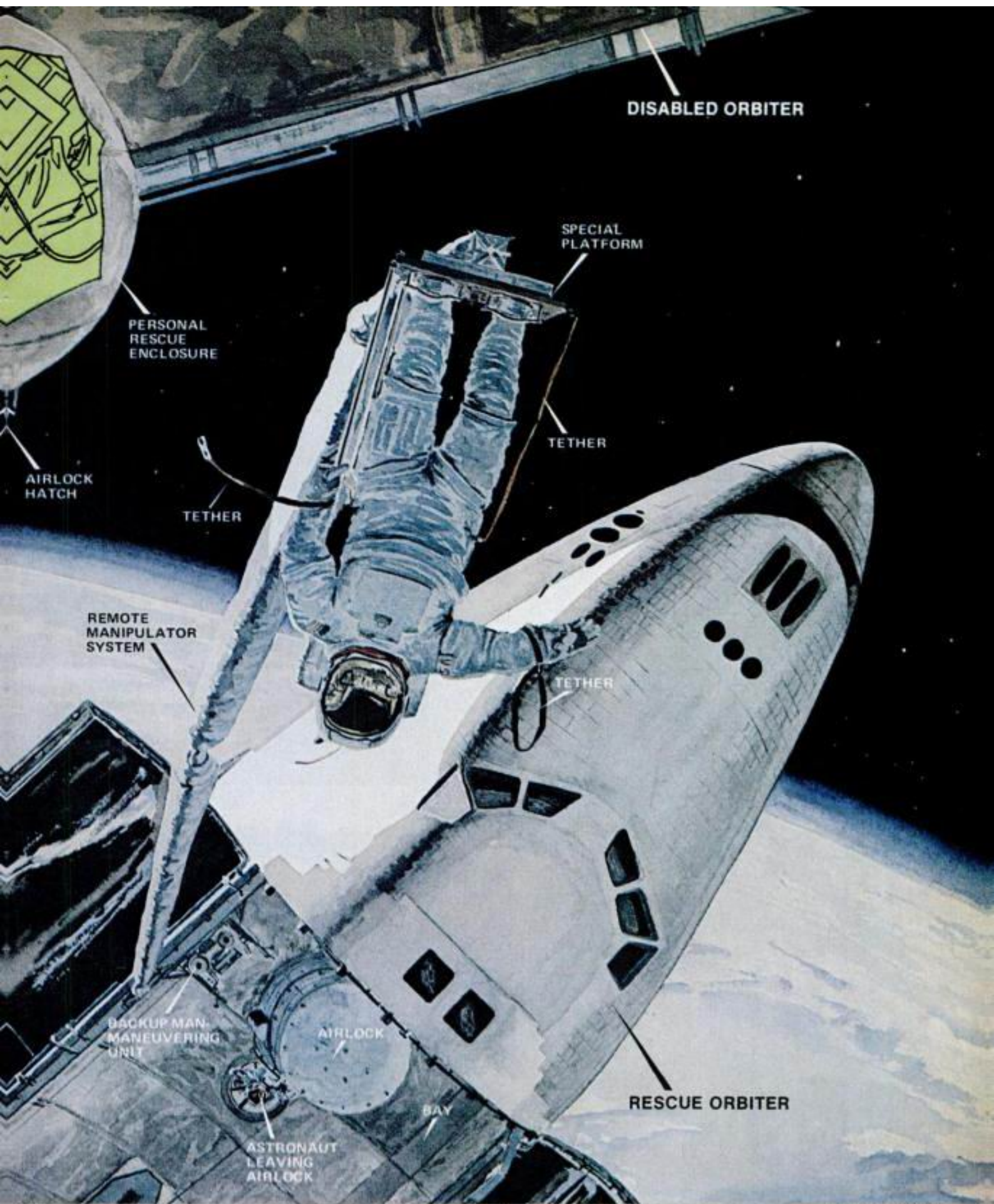
Depending on the mission, the Orbiter will be placed in an orbit ranging from 100 to 600 miles from the Earth. Typically, the craft will remain in orbit for about seven days, but will have the capability of staying up for 30 days. On re-entry into the Earth's atmosphere, the Orbiter

(Please turn to page 126)



Marooned in an orbit some 500 miles from Earth, the crew of a disabled Orbiter starts to "abandon ship." In an airlock, a suited astronaut maneuvers rescue ball through a hatch. The ball, now disconnected from the craft's life-support system, contains almost an hour's supply

of oxygen. It also has a compact communications system and a small port for visibility. Ready to grasp the ball by a fabric handle is astronaut from the rescue Orbiter. He's tethered to a small platform rigged at the end of the Orbiter's remote manipulator system. When he's



PM art; Paul Fjeld

secured the ball, the manipulator arm will retract, bringing the astronauts back to the rescue craft's bay. This painting, by artist Paul Fjeld, shows one of three rescue modes under development at the Johnson Space Center. A second method involves a clothesline device strung be-

tween two Orbiters, with the rescue ball being pulled from one craft to the other. In a third method, an astronaut equipped with a man-propulsion device simply carries the ball to the rescue Orbiter. Though the normal capacity of a Shuttle Orbiter is seven crewmen and passen-

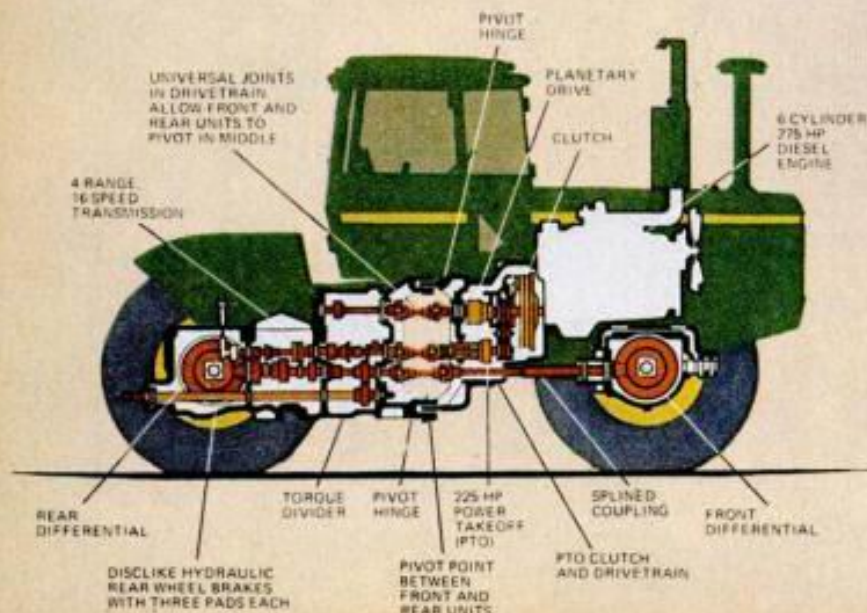
gers, as many as 10 persons could be accommodated in an emergency, according to NASA engineers. Soon after stranded astronauts have boarded, the rescue ship will use rocket propulsion to re-enter the atmosphere, then finally glide to a landing at one of its U.S. bases.

Down on the farm with four-wheel drive

by Bill Kilpatrick



"Big Red": 300 horses, four-wheel drive and incredibly push appointments make this huge 10-ton International Harvester tractor typical of what's happening down on the farm these days. Elaborate drivetrain in John Deere model (below) carries power from engine to both front and rear axles. Universal couplings allow front and rear units to pivot. A differential at each end lets opposing wheels turn at different speeds when steered.



\$50,000 for a tractor? Yup, but just see what you get for the money. Here's a look.

It didn't look like a tractor, but the man kept calling it one. "I'll tell you how it is with that tractor," he said, waving in the direction of a huge red hulk parked in a field nearby. "That disc harrow on the back of it there, that's a 28-footer, and in a 10-hour day, one man, working all

by himself, can do 150 acres." He paused, then smiled. "Now that's moving right along."

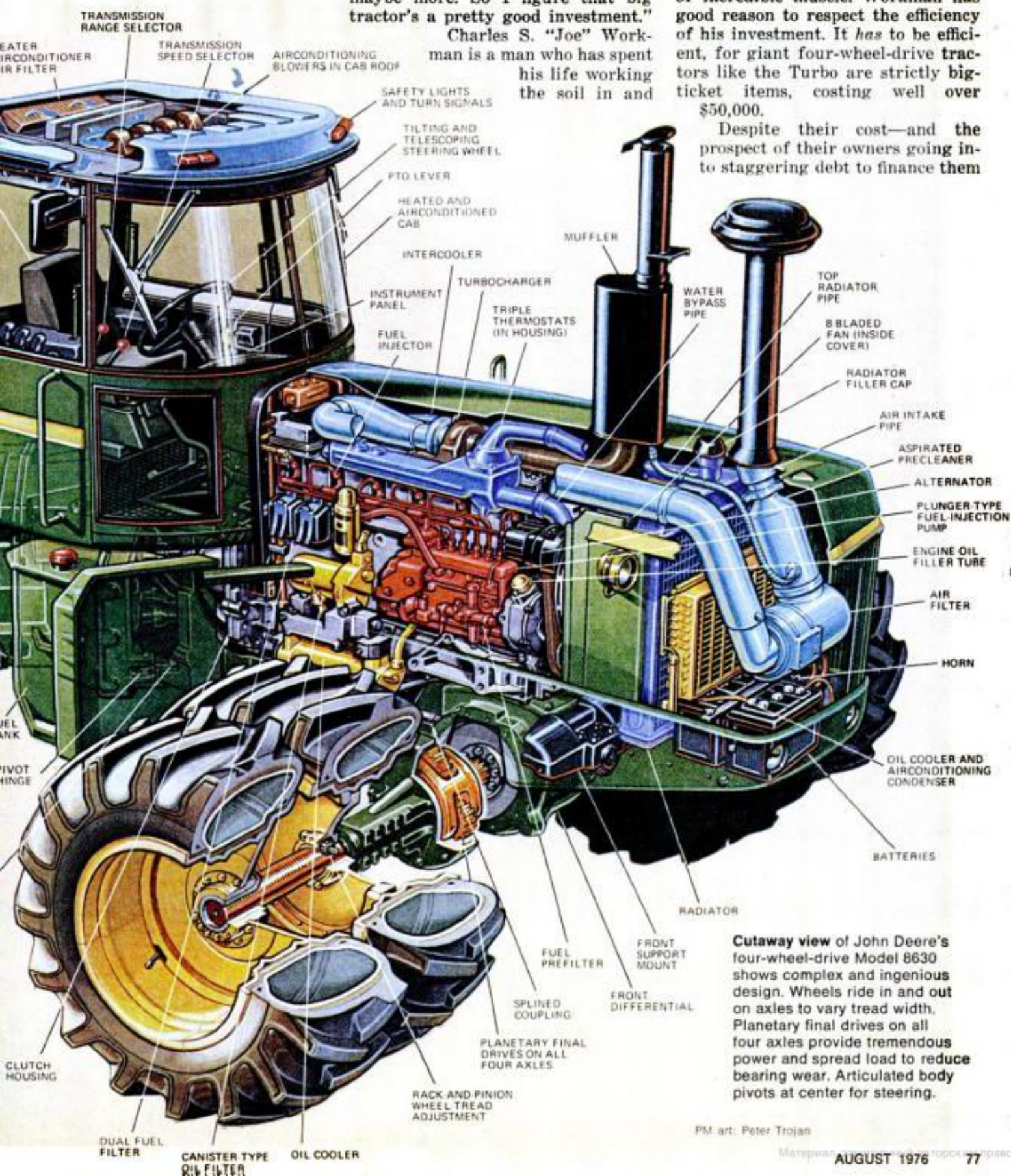
The big gain: efficiency

"Normally," he went on, "it would take two men on two tractors pulling two 15-foot harrows twice as long, maybe more. So I figure that big tractor's a pretty good investment."

Charles S. "Joe" Workman is a man who has spent his life working the soil in and

around the Delmarva (Delaware-Maryland-Virginia) Peninsula communities of Georgetown and nearby Bridgeville. He was describing a mammoth 300-hp, diesel-powered, eight-tired, four-wheel-drive, cab-enclosed, articulated International Harvester 4568 Turbo—a 10-ton mass of incredible muscle. Workman has good reason to respect the efficiency of his investment. It has to be efficient, for giant four-wheel-drive tractors like the Turbo are strictly big-ticket items, costing well over \$50,000.

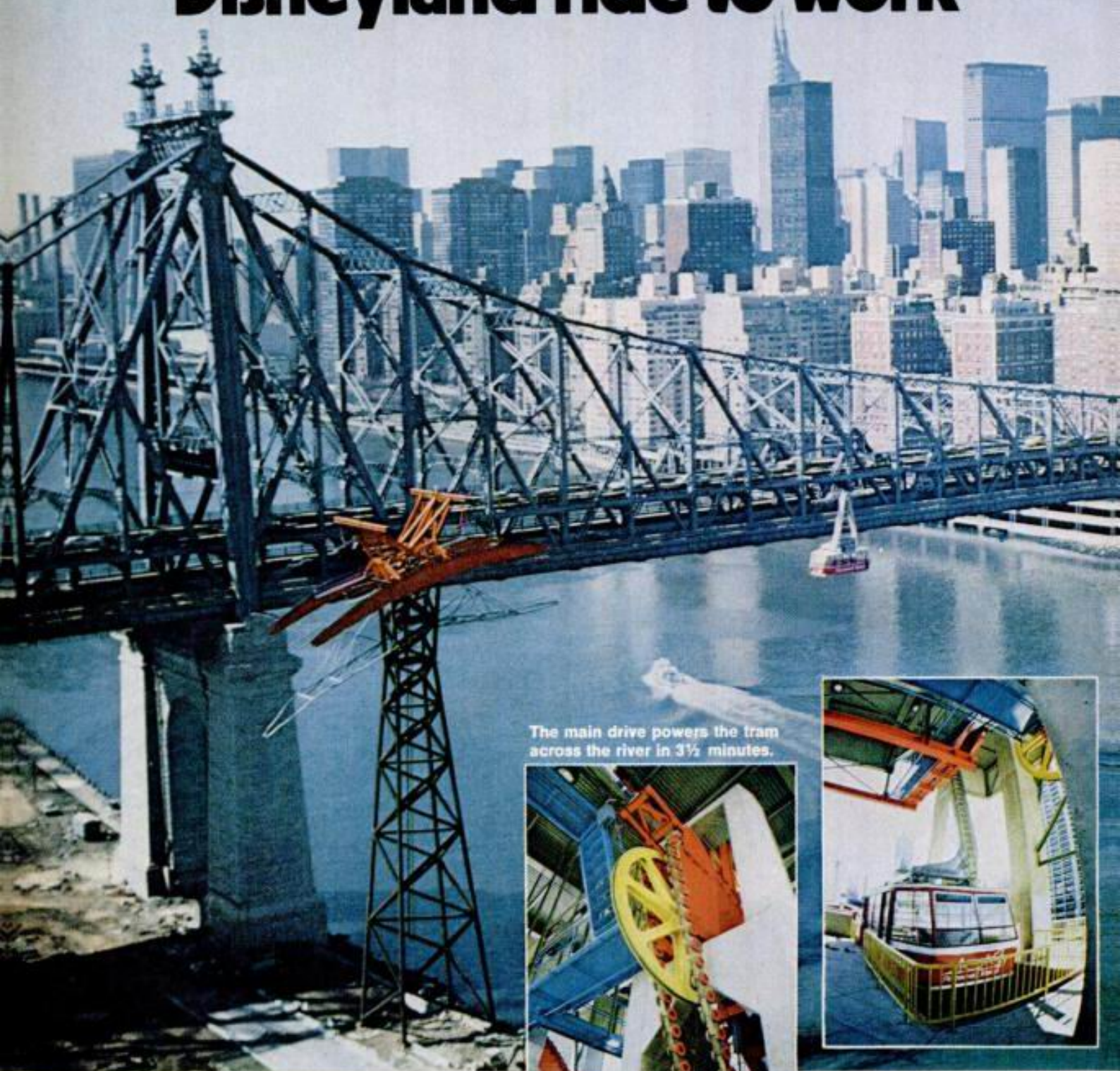
Despite their cost—and the prospect of their owners going into staggering debt to finance them



Cutaway view of John Deere's four-wheel-drive Model 8630 shows complex and ingenious design. Wheels ride in and out on axles to vary tread width. Planetary final drives on all four axles provide tremendous power and spread load to reduce bearing wear. Articulated body pivots at center for steering.

PM art: Peter Trojan

Airborne commuters take a Disneyland ride to work



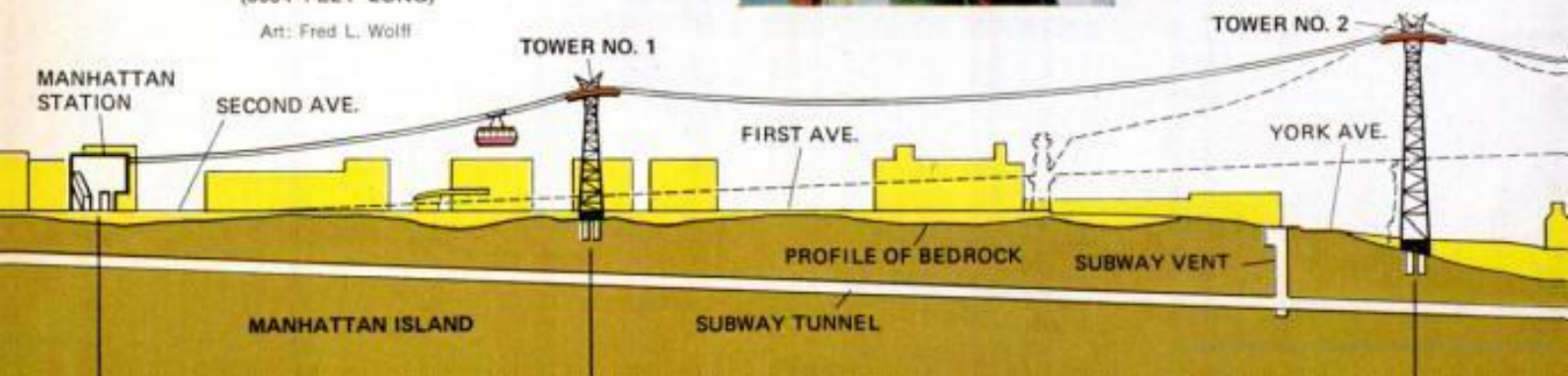
The main drive powers the tram across the river in 3½ minutes.



The gondolas settle into brightly painted stations for loading.

PROFILE OF TRAMWAY CIRCUIT (3094 FEET LONG)

Art: Fred L. Wolff



by Mike McClintock
ASSOCIATE HOME AND SHOP EDITOR

The world's first mass-transit tramway now carries commuters on a wonder ride between two islands in the heart of New York City—Roosevelt and Manhattan. In a spectacular 3½-minute skyride, travelers from Roosevelt Island in the East River literally fly by the city's horrendous rush-hour traffic, touching down in midtown Manhattan.

The tramway builder, the New York State Development Corp., hopes the unique facility will be a two-way street across the rushing river. It will serve those living in the corporation's newly built residential community on Roosevelt and those walled-in Manhattan apartment dwellers, who will have easy access to Roosevelt's recreational areas.

Passengers to and from the islands will travel in two synchronized gondolas (each holding 125 people) that load simultaneously at opposite ends of the circuit. Each cabin has an op-

(Please turn to page 112)

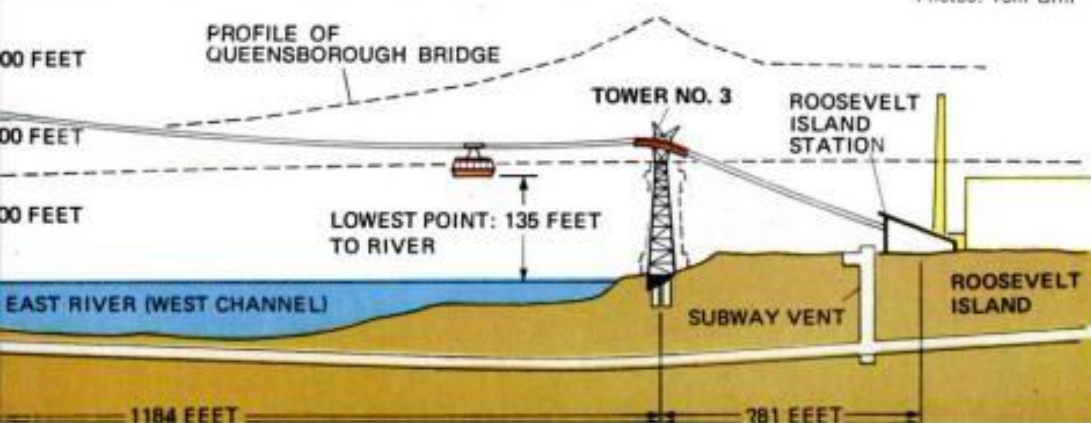
HEAD-ON VIEW, TOWER AND BRIDGE



Tramway riders will get a spectacular view as they beat the crush of rush-hour traffic.



Photos: Tom Grill



Engineers on the tower inspect cable tension as the tramway rolls by on a test run. Bridge superstructure in the background shields the cables from low-flying planes.



TRACK ROPE CARRIAGE (WITH 32 ROLLERS)

BRAKE TROLLEY

1-13/16" STEEL TRACK ROPES

1-5/8" STEEL HAUL ROPE

ROOF HATCH

ROOF VENT

An offset balanced arm carries the car on the power carriage with 32 wheels. The cabins can hold 125 passengers and a total payload of 21,250 pounds. Controls in the gondola can be overridden from the master control booth in the station and both the drive and brake units are backed up by standby systems. At 17 mph, the ride is smooth and steady.



GONDOLA

CAPACITY: 125 PASSENGERS
WEIGHT: 18,300 LBS.
SIZE: 24'11" x 12'10"

POSITION LIGHT

AIRBORNE COMMUTERS

(Continued from page 53)

erator, although the full length of the system is managed and constantly monitored from a control booth at the station. Wrap-around windows offer riders spectacular views as the cars rise from the loading docks and quickly reach the tracking speed of 17 mph.

Users avoid parking problems

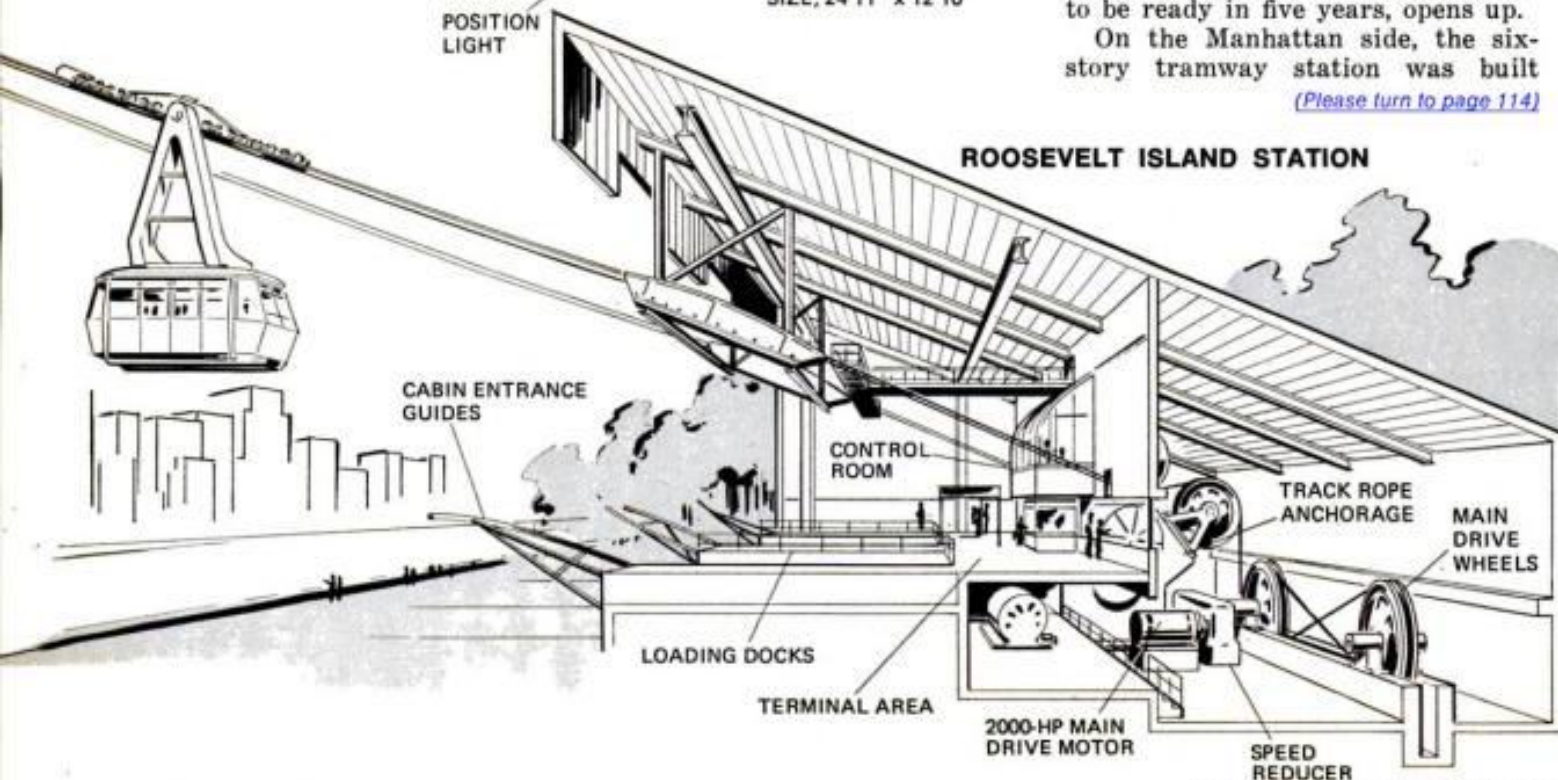
In addition to whisking past the bumper-to-bumper traffic on the adjacent Queensborough Bridge, the real bonus to commuters will be avoiding the hassle of parking in the city. Many residents don't need cars at all since transportation is provided throughout Roosevelt Island by electric buses.

This system is one addition to modern mass transit that stands a good chance of succeeding. One factor is that the only alternate commuting route is a typical New York bus and subway combination that can take 45 minutes or longer. There will be no competition until a subway stop, to be ready in five years, opens up.

On the Manhattan side, the six-story tramway station was built

(Please turn to page 114)

ROOSEVELT ISLAND STATION



War watch in the Sinai

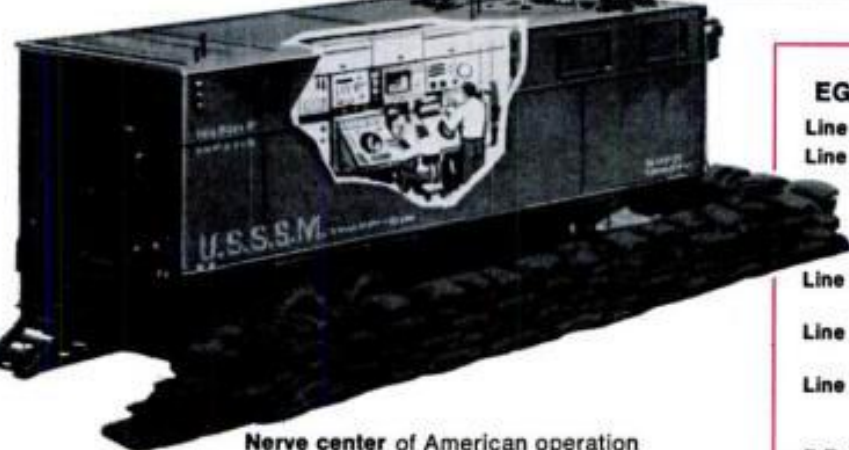
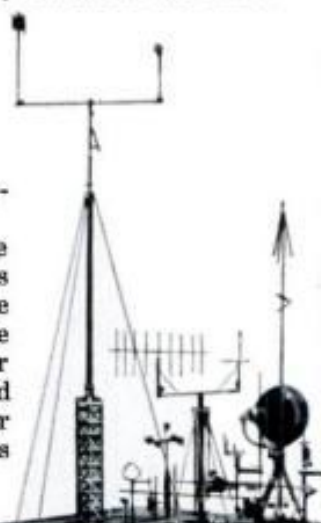
by Edward Hymoff

At about the time this issue of *Popular Mechanics* hits the newsstands, a group of American electronics technicians will be settling down to their new jobs in the Mideast—and perhaps wondering if they made the right decision.

The jobs, filled earlier this year, became available last October when the United States Congress passed a joint resolution authorizing 200 Americans to participate in an early warning system designed to keep the peace between the armed forces of Egypt and Israel. The resolution carried a major stipulation: The technicians must be civilians and they must be "individuals who have volunteered to participate in such a system."

By the end of December, more than 2000 applicants, many of them Vietnam veterans, had written to the State Department and the Pentagon in response to news reports about the undertaking. The flood of mail came in despite the fact that the jobs might be of limited duration and in a place that had been a battlefield many times in the past and could become one again.

This is the Sinai, the biblical land where Moses is said to have received the Ten Commandments, where temperatures often soar above 110° F. in shade and drop below freezing after sunset, where sandstorms



Nerve center of American operation is sensor reporting post (SRP) similar to installation shown. Here, signals from sensors are analyzed for signs of aggressive moves by Egypt or Israel.

**EGYPT-ISRAEL AGREEMENT—SEPTEMBER 1975**

Line E: The Egyptian line.

Line J: The Israeli line.

The lines E and J extend 12 nautical miles into the Mediterranean Sea perpendicular to the direction of the coast; the area between the lines is the U.N. buffer zone.

Line K: The limit of the Israeli area of limited forces and armaments.

Line F: The limit of the Egyptian area of limited forces and armaments.

Line M: The line separating the Israeli-controlled area from the area south of line E and west of line M, and the areas of buffer zones 2A and 2B.

B.Z.-2A, B.Z.-2B: The buffer zones along the Gulf of Suez.

E-1: Egyptian surveillance station.

J-1: Israeli surveillance station.

scour ravines and passes, only to give way to calm winds and clouds of mosquitoes and sand fleas. It is a harsh, bleak, unforgiving land, better suited to the ways of scorpions and vipers than to man.

The Sinai is a triangular-shaped region that stretches some 240 miles from north to south and 150 miles from east to west. The northern part is a relatively level desert. In the south the land rises, breaking into

granitic ridges, some of them more than 7800 feet high.

But the focus of world attention is now directed at a small pocket of the Sinai, located some 30 miles northeast of Suez, the southern entrance to the Suez Canal. This pocket is the gateway to Egypt from the east, and the historic invasion route to Israel from the southwest. If all goes according to schedule, by late February of this year two key passes through the hills—the Giddi



and the Mitla—will have been sowed with antennas, microwave dishes, and other “seeds” and “plants” that see, hear, and feel.

These exotic surveillance devices were developed in the mid-'60s for use in Vietnam. They were planted in jungles to warn GIs of Vietcong intruders, were dropped by aircraft to pinpoint targets for Air Force and Navy bombers, and were concealed in marshes and riverbanks

The electronic battlefield became a reality in Vietnam. As illustration shows, sensors, transmitters and other gear—similar to equipment developed for Indochina—are used to “wire” the two key passes in the historic Sinai.



The wind shifts to windmills

by William and Ellen Hartley

When Henry and Retta Clews built their home in the Maine woods a few years ago, they found the cost of running in power lines too high for their budget. Not content to settle for kerosene lamps and the inconvenience of doing without electrical appliances, the 29-year-old former high-school science teacher decided to install a generating system—a decision that ultimately put him in the windmill business.

For \$2800 he bought an Australian Dunlite windmill system and 40-foot steel tower. His wife and brother-in-law helped him with the installation.

"The tower comes in all these little pieces and must be bolted together," he explains. "It's the biggest Erector Set you ever saw. We chose to set the base first and build the tower up from the ground, which is not too hard if you're not scared of heights. The top is as high as a five-story building."

The system proved capable of lighting eight 75-watt bulbs every evening and of running a TV, stereo, electric typewriter, blender, toaster, vacuum cleaner, portable saw, electric drill and a 1/2-hp water pump.

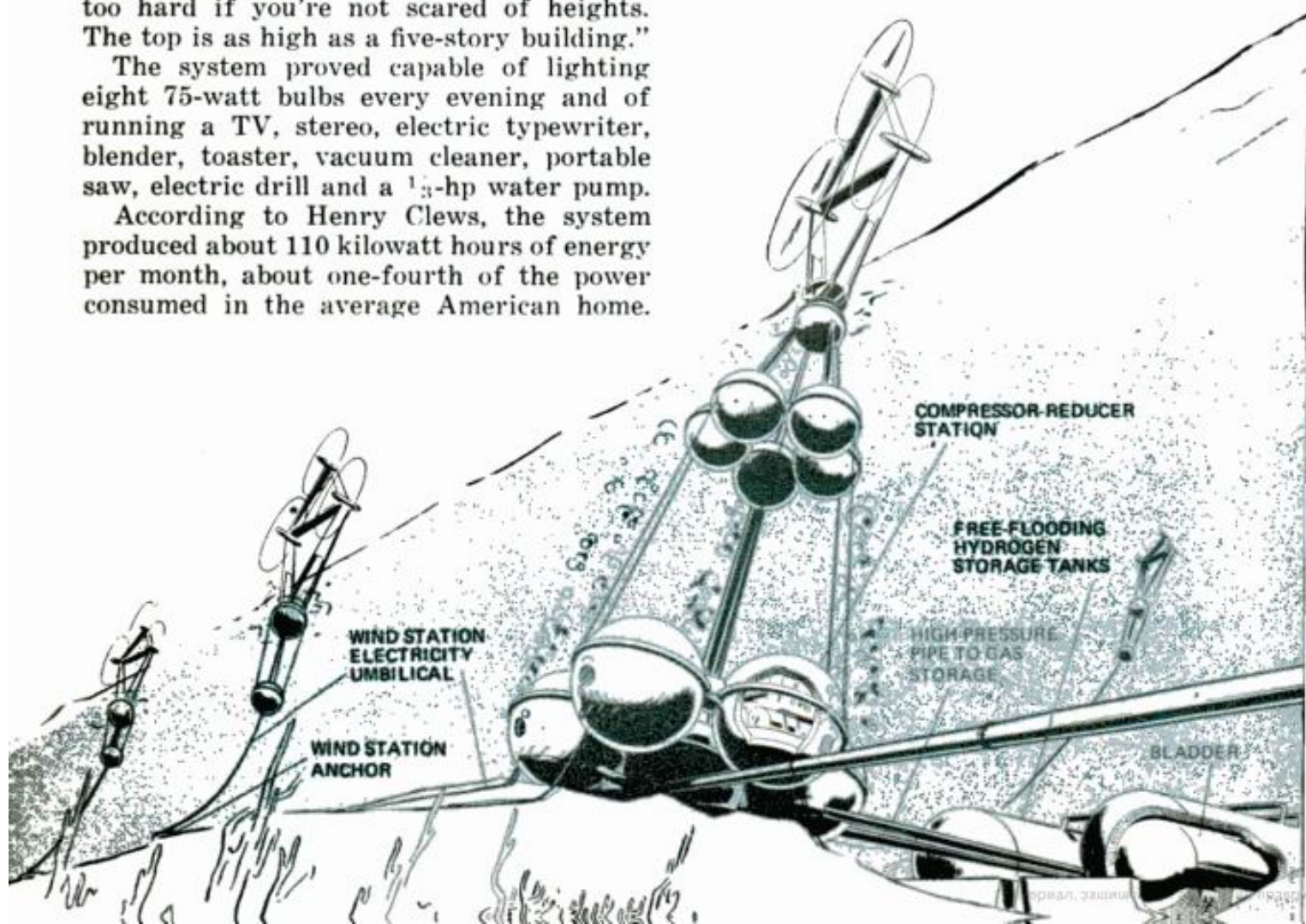
According to Henry Clews, the system produced about 110 kilowatt hours of energy per month, about one-fourth of the power consumed in the average American home.

Later, he added a Swiss-built Elektro windmill to provide further capacity.

Henry Clews did more than solve his power problems when he turned to the windmill. He also found himself a livelihood as the American representative of the Australian and Swiss windmill makers. During his first year in business, he sold 15 complete systems—one small indication of the current interest in wind-generated power.

In contrast to Henry Clews's focus on the problem of providing power for the individual home, men like William E. Heronemus are thinking in terms of how the wind can be used to provide energy for large sections of the nation. Professor of civil engineering at the University of Massachusetts, Heronemus and his colleagues have produced studies of windmill systems for the New England and Lake Ontario regions as well as other areas.

Heronemus foresees, for example, a vast network of windmills floating off the coast of New England, each of the hundreds of



A vast network of floating wind generators would be strung out off the New England coast if a concept developed by Prof. William Heronemus becomes reality. System would produce hydrogen through electrolysis of seawater. Hydrogen would be stored in deep-water tanks, from which it would be pipelined ashore to produce electricity in fuel cells. Electrolyzer units and compressor stations would be manned.

WIND TURBINE GENERATORS
200' DIA.
160' FROM OCEAN SURFACE
GIMBAL
BUOYANT AND ACCESS LEGS
LIVING QUARTERS
ELECTROLYZER UNIT
PURE WATER TANK
ELECTRICITY UMBILICAL
WORK AREA
HYDROGEN GAS COLLECTION AND DISTRIBUTION PIPELINE
BALLAST SPHERE
STEEL PIPE WALL
CONCRETE BALLAST
ELECTROLYZER STATION ANCHOR
HIGH-STRENGTH HOSE

200' DIA.

160' FROM
OCEAN SURFACE

GIMBAL

BUOYANT AND ACCESS LEGS

LIVING QUARTERS

ELECTROLYZER UNIT

PURE WATER TANK

HYDROGEN GAS COLLECTION AND DISTRIBUTION PIPELINE

ELECTRICITY
UMBILICAL
PENETRATIONS

BALLAST
SPHERE

CONCRETE
BALLAST

STEEL PIPE WALL

ELECTROLYZER
STATION ANCHOR

'Big iron' moves to the North Sea

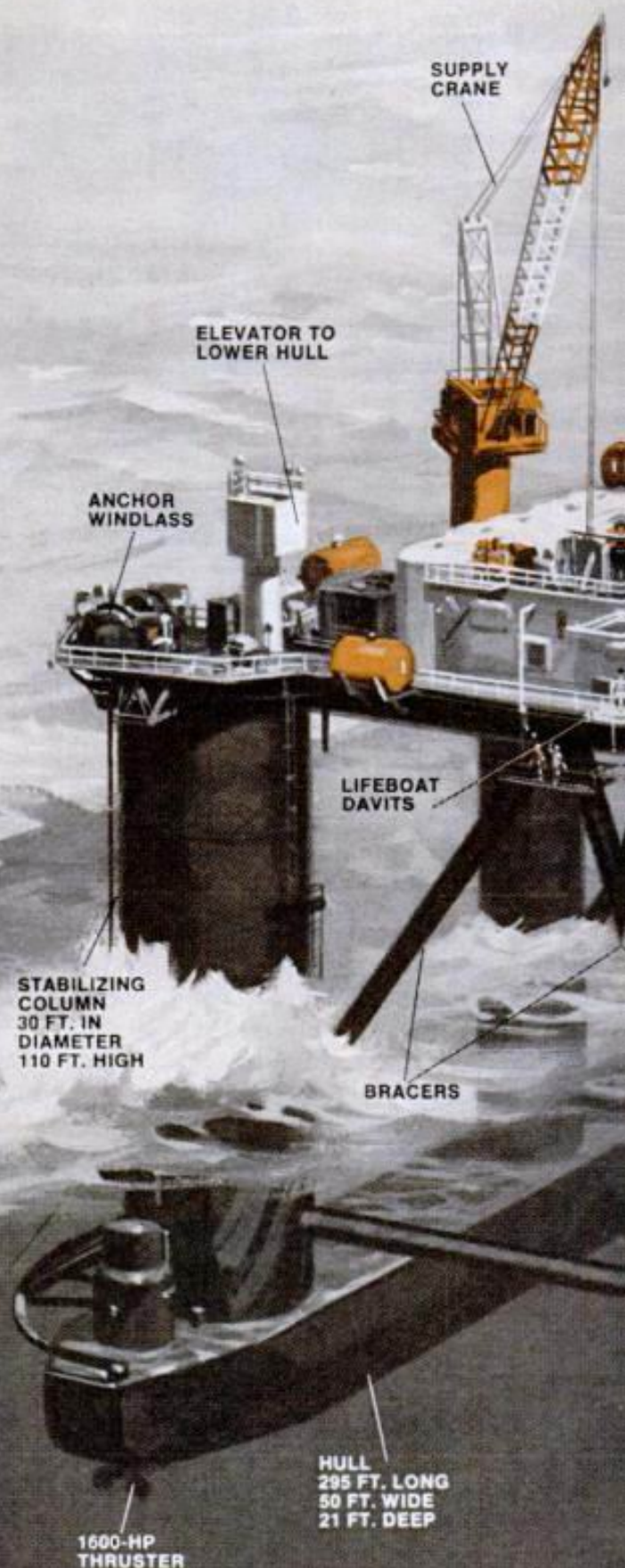
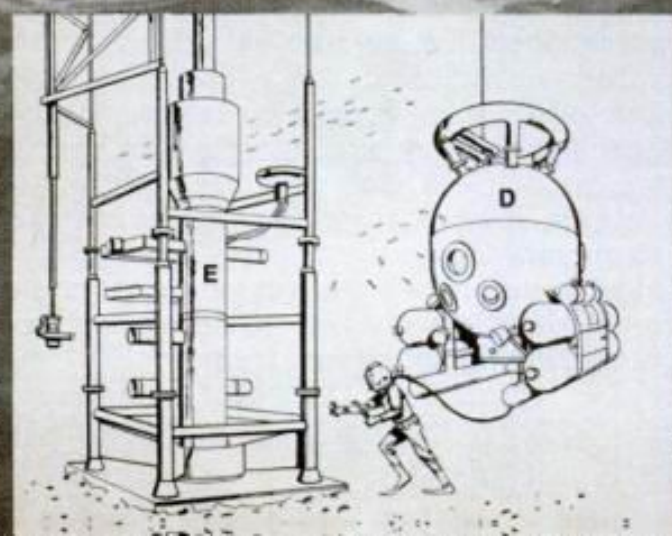
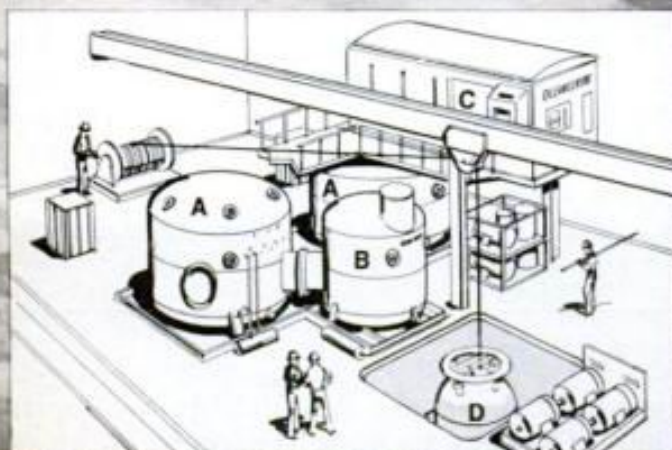
by John F. Pearson

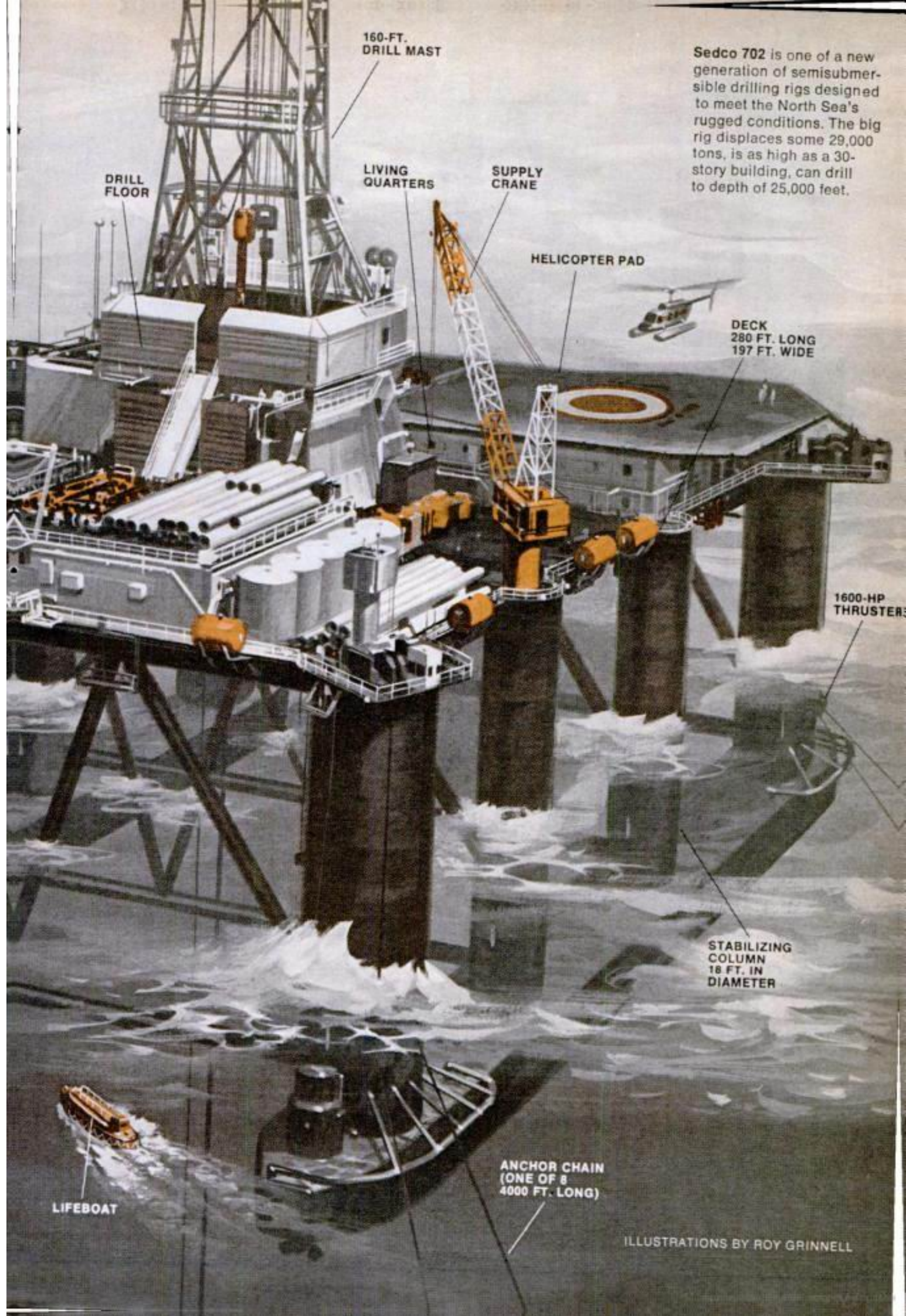
SCIENCE EDITOR

Even under the best of conditions, drilling for offshore oil is dangerous work—but in the North Sea it can be a wind-lashed nightmare.

In this small arm of the Atlantic—600 miles long and 400 broad at its widest latitude—you can encounter some of the most savage offshore weather in the world. It takes tough, capable men and the stoutest of vessels to stand up to the North Sea, especially in winter when storms bring 90-foot waves and 100-mph gusts, when air temperatures drop below freezing and water temperatures dip under 40° F. A swift change in

Oceaneer 1000 saturation diving system is installed in an enclosed space on the deck of the Sedco 702. Four divers live in the two deck decompression chambers (A), equipped with bunks, washbasins, shelves and lockers. They move into the diving bell (D) through the transfer chamber (B), which mates with the bell. The system is monitored and controlled from van (C). On sea bottom, diver moves from the bell to inspect blowout stack (E). The sophisticated system is designed to permit divers to work at depth of 1000 feet.





160-FT.
DRILL MAST

DRILL
FLOOR

LIVING
QUARTERS

SUPPLY
CRANE

HELICOPTER PAD

DECK
280 FT. LONG
197 FT. WIDE

1600-HP
THRUSTER

STABILIZING
COLUMN
18 FT. IN
DIAMETER

ANCHOR CHAIN
(ONE OF 8
4000 FT. LONG)

LIFEBOAT

ILLUSTRATIONS BY ROY GRINNELL

Sedco 702 is one of a new generation of semisubmersible drilling rigs designed to meet the North Sea's rugged conditions. The big rig displaces some 29,000 tons, is as high as a 30-story building, can drill to depth of 25,000 feet.



KEY

- ① RESCUE HELICOPTER
- ② SMOKE TOWER
- ③ SPRINKLER
- ④ FIRE CALL BOX
- ⑤ SMOKE-FREE STAIRS
- ⑥ HELICOPTER PAD
- ⑦ SKY VAN
- ⑧ FIRE SEPARATION WALL

Art by Fred Wolff

"SURVIVAL" SKYSCRAPERS MIGHT INCORPORATE features shown: areas with fire-resistant walls, smoke towers to insure clear stairways, alarm boxes on each floor, exterior emergency elevators and sprinklers

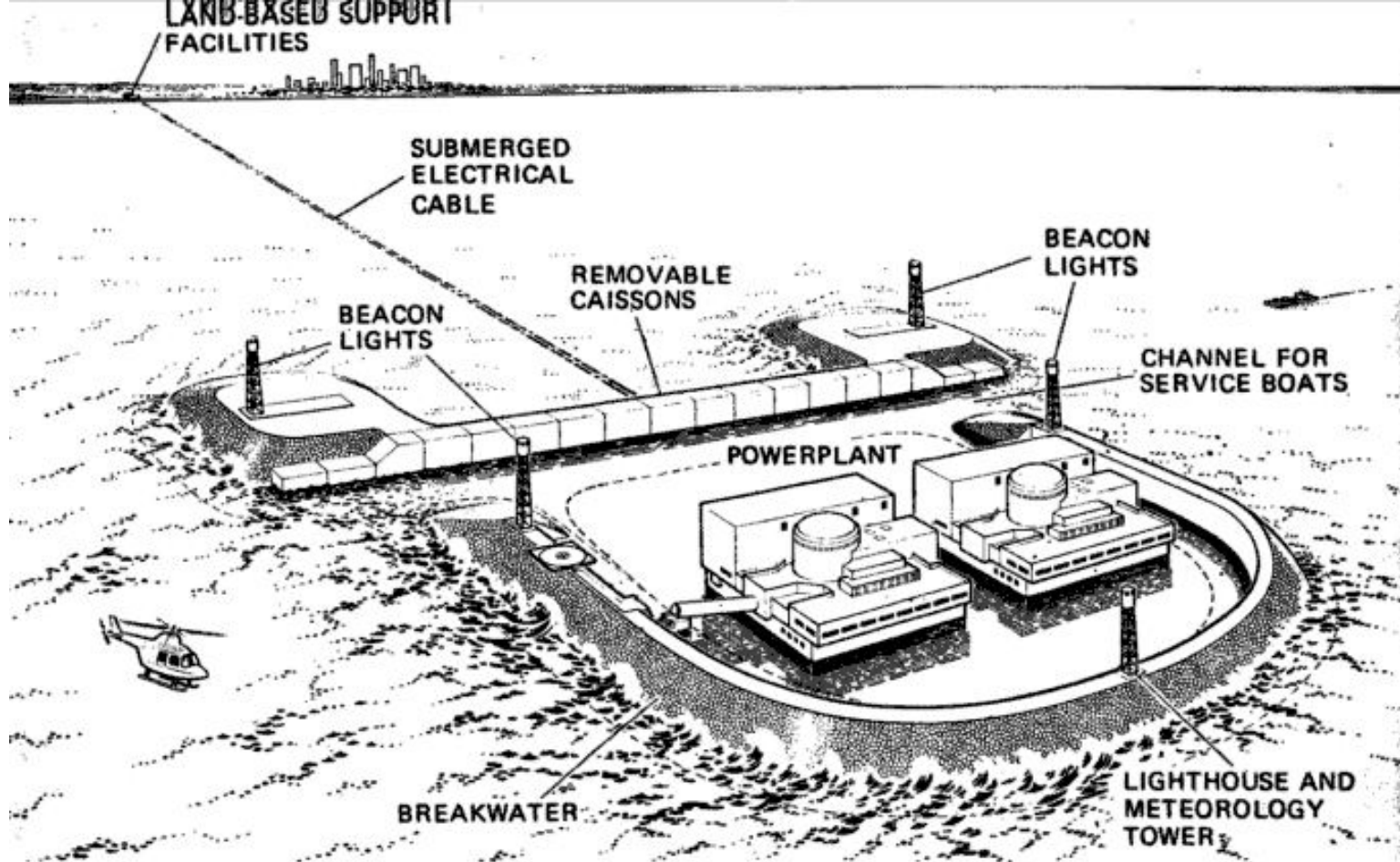
evacuated as smoke permeated the building. It took an observant guard in an adjoining structure to call the fire department.

The first group of firemen were trapped in an elevator at the fourth floor and had to chop their way out to escape the heavy smoke. Others found elevators which took them to the 30th floor. Hoses were attached to standpipes in the stairways, but the smoke was so severe that masks had to be used, the heat so great that the fire-fighters could work only for minutes at a time.

In an older building, the windows

could have been opened to vent the heat, gases and smoke. At One New York Plaza they were locked with special latches, and the firemen broke the heavy glass with great difficulty.

Five hours later the fire was under control, but only after a second and third alarm, and 25 pieces of equipment and 150 firemen had been brought in. A nearby hospital was overwhelmed with choking victims, many semiconscious and retching. Police helicopters hovered overhead to rescue possible survivors from the roof, but a floor-by-floor search disclosed no more occupants—dead or alive. One thing



Coming: Offshore nuclear powerplants

By JOHN F. PEARSON, Science Editor

Technical illustrations by Peter Trojan

AN UNUSUAL CEREMONY took place last September aboard a yacht off the New Jersey coast. In the main salon, before several dozen witnesses, two men signed their names to a contract. One man represented the Public Service Electric and Gas Co. of New Jersey, the other, Offshore Power Systems—and the contract called for an outlay of \$750 million for the world's first floating, offshore nuclear powerplant.

The seaborne ceremony was held in the vicinity of the proposed site, a point in the Atlantic just under three miles east of the coast and 12 miles northeast of Atlantic City. (By keeping the plant within New Jersey's three-mile limit, legal aspects of the project are simplified.) At the site, in 40 feet of water, engineers will build a breakwater to shelter the two floating units—each capable of generating 1.15 million kilowatts—that will make up the powerplant. Power will be transmitted to shore via underwater cable.

Environmental problems on land have caused nuclear-power developers to look to the oceans. Plants sited on rivers and estuaries tend to cause ecological upheavals with the release of huge amounts of heated water. The same water supposedly would not cause much of a stir in the ocean. In addition, a plant located miles from the nearest shore would pose less of threat in the event of a nuclear accident.

The project represents advanced thinking in more ways than

one. Offshore Power Systems—a joint venture of Westinghouse Electric Corp. and Tenneco, Inc.—will build the 140,000-ton PMNPs (Platform Mounted Nuclear Powerplants) on an assembly line.

Preliminary work on the manufacturing facility has already begun on a 900-acre site in Jacksonville, Fla. A major feature will be a broad slip leading to a nearby waterway. Honeycomb platforms—about 400 feet on a side—will be fabricated at the start of the slip. They will then be moved down the slip and stopped at assembly stations where 650-ton gantry cranes will load on board various components, some weighing as much as 600 tons.

A completed PMNP will be floated out at the end of the slip and into the waterway for mooring at a testing area. After it's checked out, it will be towed seven miles to the Atlantic and then to its final destination. The first such tow—to the New Jersey site—is planned for 1979. According to present schedules, PMNP production (at a rate of two units a year) will start in mid-1975.

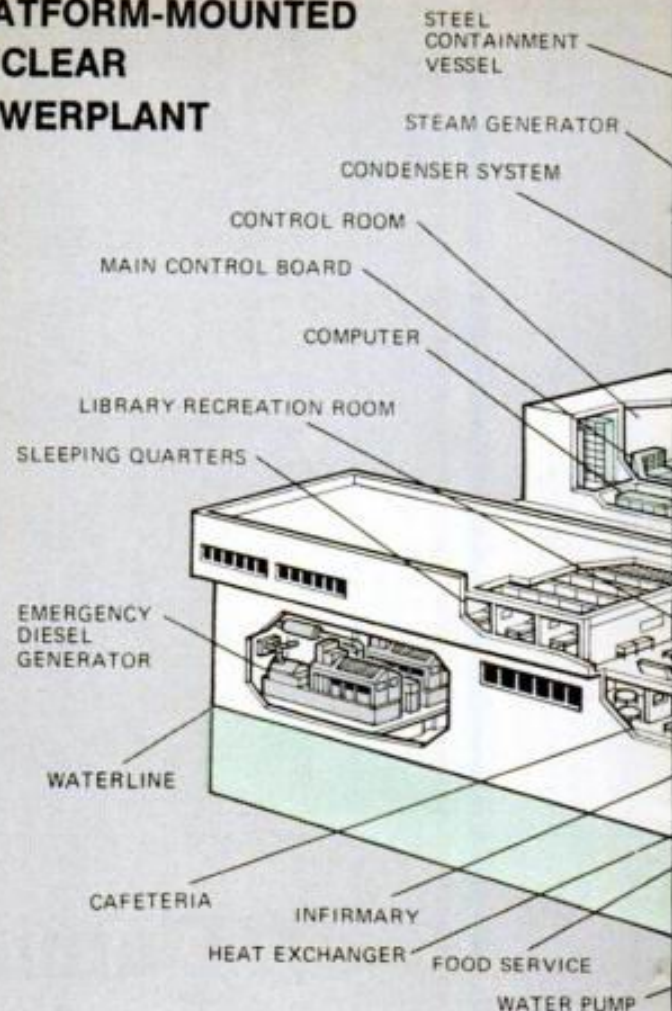
Work on the breakwater will begin in 1976. The U-shaped section, which will face the ocean, will be built first. Then after the two PMNPs are moored, the straight section facing land will be installed.

Some 3 million tons of concrete and other material will go into the building of the breakwater. It will measure 30 feet across at the top and 300 feet at the bottom, and will have enough heft to withstand hurricane-force winds and 43-foot waves—those that occur once in 100 years. The powerplant should be able to continue operating even during such a storm.

The breakwater will also provide solid protection for the PMNPs in the event of a ship collision. Impact studies indicate that a 190,000-ton tanker would do relatively little damage to the breakwater. Ships larger than that would have too deep a draft to even get close. In addition, the facility is located away from the normal shipping lanes.

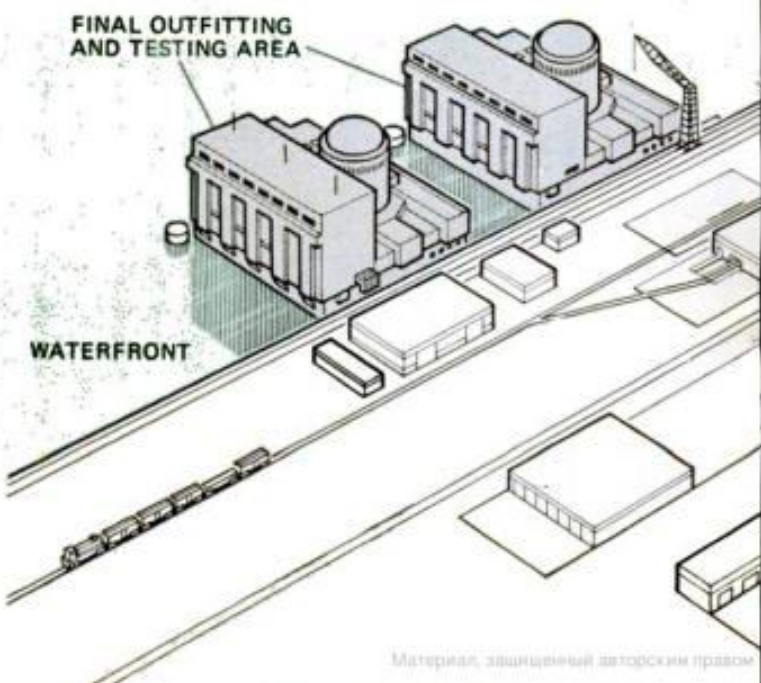
The cost of the breakwater—\$250 million—will shoot the total price tag to \$1 billion. But this outlay, according to Public Service officials, will help insure an adequate power supply for New Jersey in the 1980s. ★ ★ ★

PLATFORM-MOUNTED NUCLEAR POWERPLANT



THE FLOATING PLANT'S equipment, facilities, safety systems and general layout are very similar to those of a conventional, land-based nuclear generating station. The supporting platform measures 400 feet long, 378 feet wide and 40 deep

SUPERSIZE ASSEMBLY FACILITY will be built in Jacksonville, Fla. Floating platforms will be fabricated at beginning of the slip. Then, at assembly stops, massive components will be swung aboard and positioned. At the start, production schedule calls for two finished units per year



Coming: A 'flying saucer'

THERE MAY BE NO SUCH THING as flying saucers from outer space, but that doesn't mean you won't be seeing them in the skies if Australian inventor Duan Phillips has his way. Phillips has come up with a saucer-shaped flying disc that lands and takes off vertically like a helicopter, but is said to have seven times the lift of a conventional copter. The disc is spun like a top by a centrally mounted engine. At the same time, air is drawn in by a blower and expelled at high pressure across the disc's upper surface. Centrifugal force created by the spinning motion accelerates the air, adding increased speed to the flow. The effect is similar to that of an airplane wing flying through air at high speed. The rapid flow of air over the curved surface of the disc produces a low-pressure area above the saucer, providing tremendous lift. A separate steerable air jet would give forward thrust, control direction of movement and serve the same function as the tail rotor on a helicopter to stabilize the craft and keep the central portion from turning with the disc. Passengers and crew would ride in a circular bubble-like canopy on top of the disc. The spinning saucer would have the natural stability of a gyroscope and be virtually crashproof. Even if the engine failed, the flywheel action of the coasting disc would continue to supply sufficient lift for a safe glide back to earth.

AIR FLOWS OVER WING AT HIGH SPEED, CREATING LOW PRESSURE AREA THAT PROVIDES UPWARD LIFT

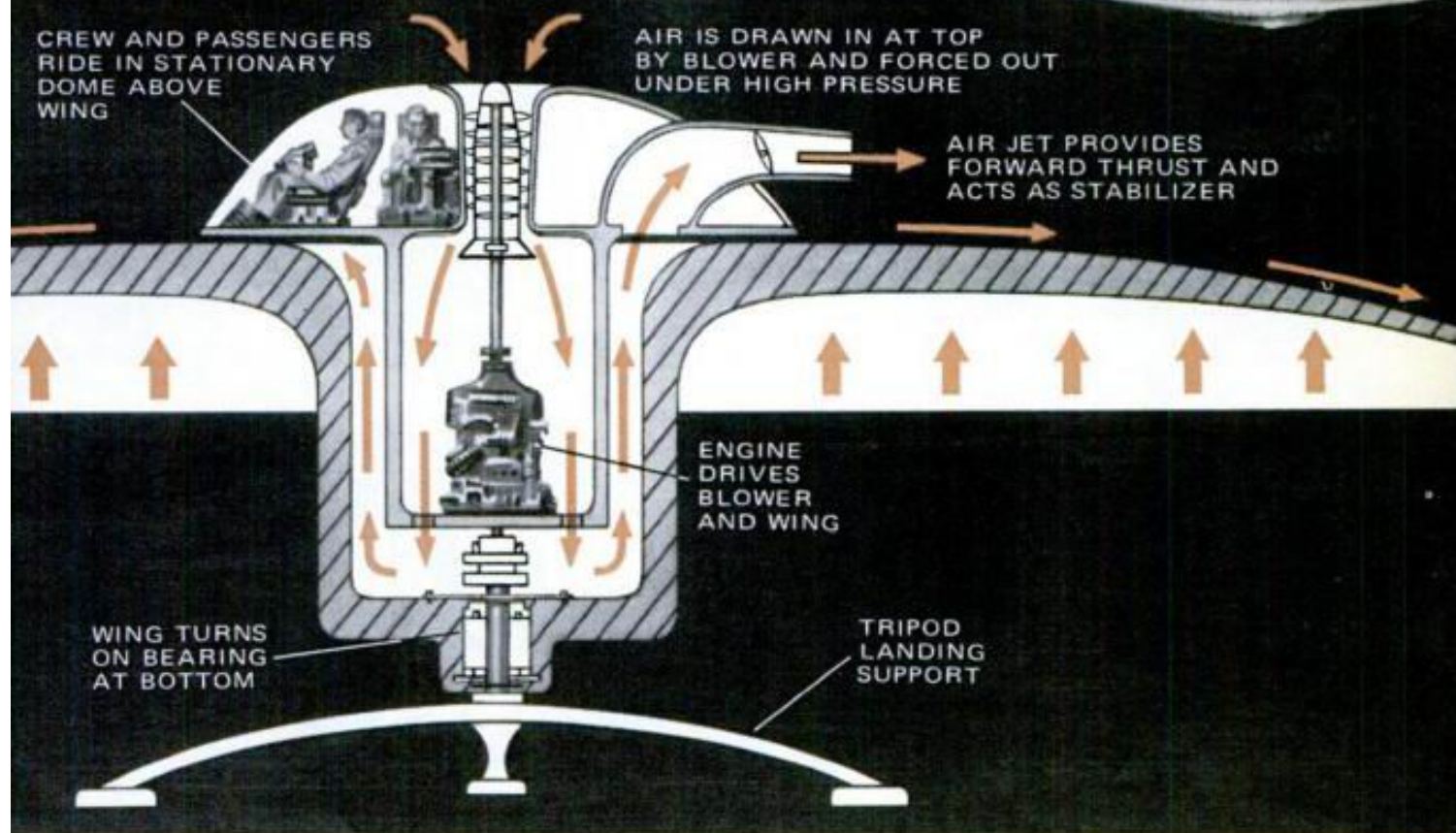
SPINNING DISC-SHAPED WING



Now: water skis with hydrofoils

If plain old water skiing isn't thrilling enough for you, you can now do it on hydrofoils. The foils, made to clamp on regular water skis, raise the skis off the surface and permit such exciting acrobatics as diving, climbing, making sharply banked turns and bobbing like a porpoise. They also reduce water drag, enabling you to go faster on less power. They come in several lengths depending on how high you dare "fly" and range in cost from \$50 to \$75. Available from Custom Dynamics, Inc., 119 River St., Waltham, Mass.

that really flies

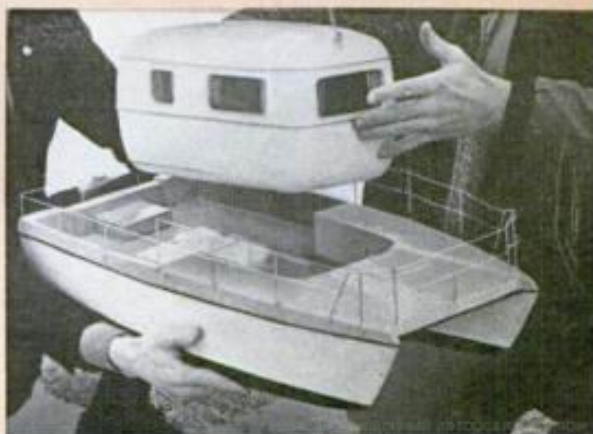


Rent-a-hull for house trailers

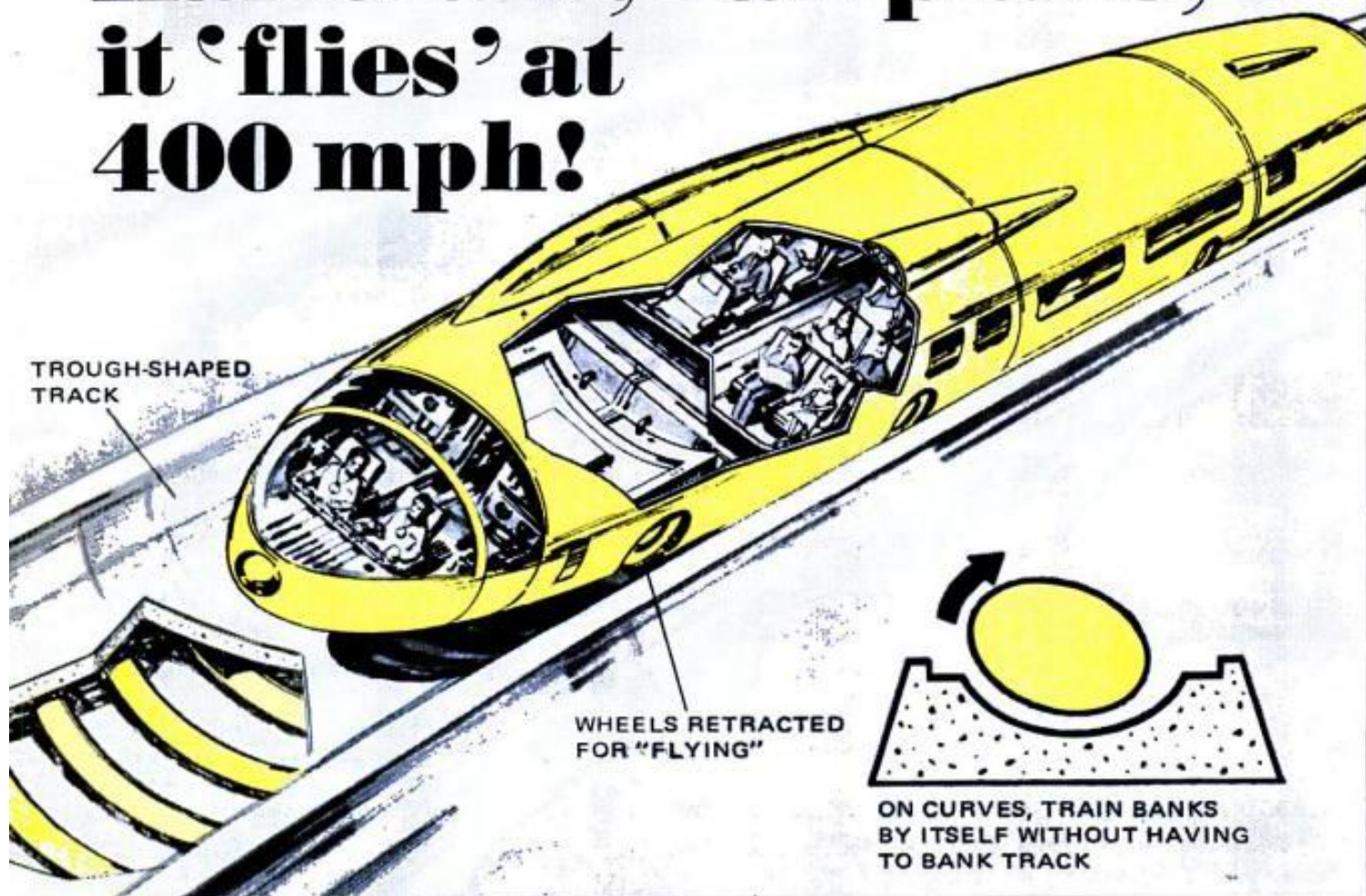
You could vacation on land or water with this convertible house trailer. When you reach a lake or river, you just drive into a special rent-a-hull marina, a crane drops your trailer into a waiting catamaran, and you're off in your own houseboat. The trailer is designed so its body lifts easily off the underframe and wheels and fits into a matching cutout in the catamaran's deck. It's the idea of Danish inventors Leif Smitt and Ole Svendsen.

AUGUST 1972

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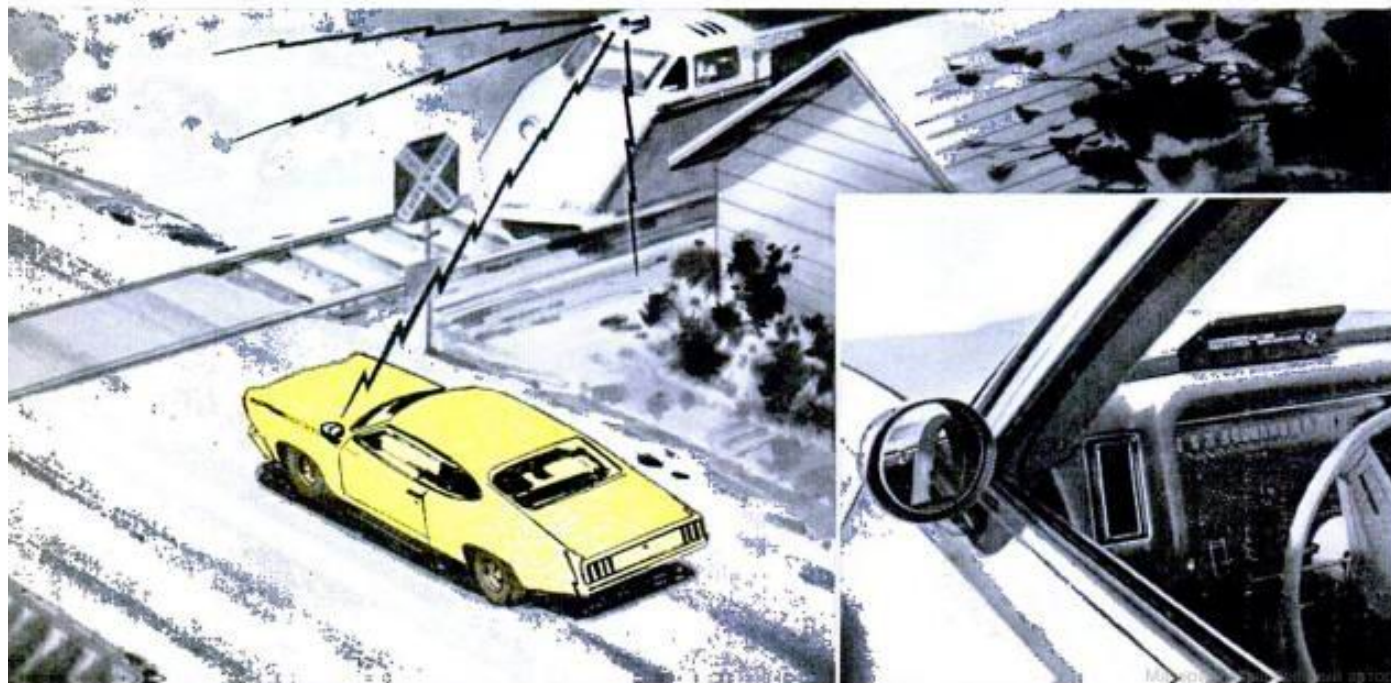
Half train, half plane, it 'flies' at 400 mph!

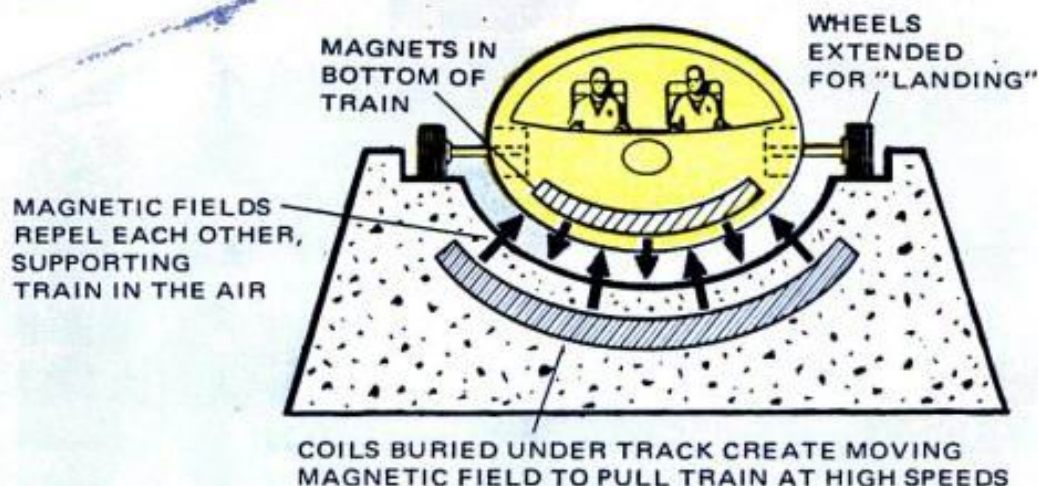


Electronic 'ear' helps make driving safer

Driving along with the windows closed and radio blaring often makes it difficult to hear warning signals such as train whistles, sirens and the horns of other motorists. With this outside "ear," there'd be no problem. An amplifying device hidden in the

rear-view-mirror housing picks up sounds and triggers a dash-mounted indicator inside the car. A light flashes on and an audible warning sounds to tell you danger is approaching. Inventor is James R. Thomas, Fort Worth, Tex.





IT DOESN'T FLY ON AIR, yet it zooms along at up to 400 mph without touching the ground. Called the Magneplane, it's designed to combine the speed and comfort of air travel with the greater safety and lower cost of land travel. The 200-passenger wingless craft is actually supported on a magnetic field as it rides in a troughlike track. Magnets in the floor interact with coils embedded in the trough to produce a field of opposing forces that keep the vehicle suspended virtually friction-free a few inches above the track. At the same time, the magnetic field moves rapidly from coil to coil, pulling the craft along

with it. The speed can be controlled merely by varying the rate of the moving magnetic field along the track.

The track doesn't even have to be banked at curves because the craft banks itself like a plane, automatically assuming the correct angle proportional to speed and curvature. By contrast, rail roadbeds must be banked to a fixed angle and are limited in speeds they can safely handle. Small retractable wheels on the Magneplane are used only for "landings" and "takeoffs" at station stops. The project is currently under study by scientists at Massachusetts Institute of Technology.

Flip-top can turns into a disposable mug

They've added a new wrinkle to flip-top beer and soft-drink cans. As you pull a tab, a metal strip peels open the top and at the same time curves outward to form a convenient handle for easy drinking directly

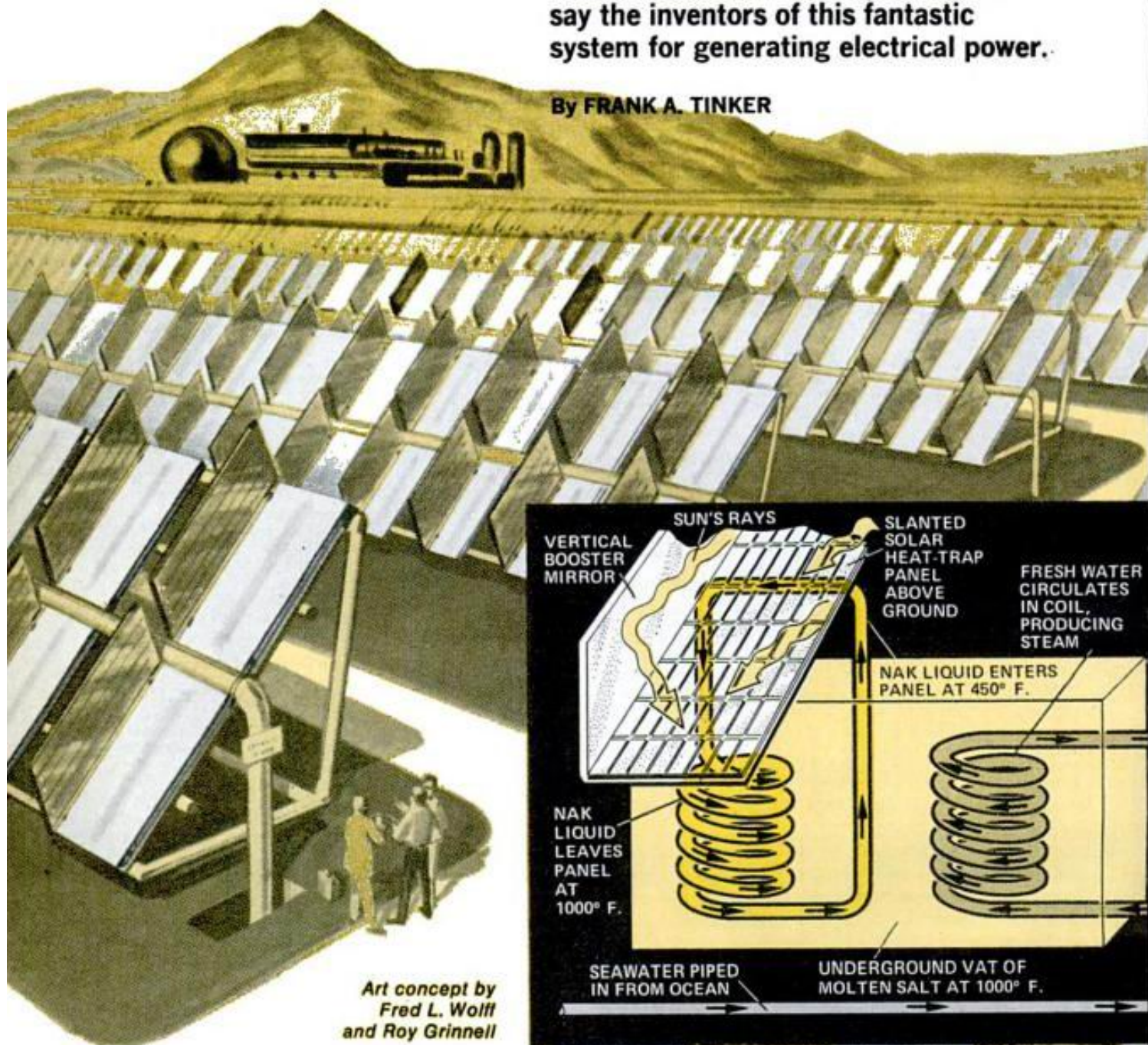
from the container. Handy for camping trips and picnics where glasses often aren't available, the self-handled can was invented by David E. Russell, 110 Riverside Ave., Jacksonville, Fla.



Will solar farming solve our power crisis?

Plant a few thousand square miles of useless desert with heat-producing sun traps and you have a solar furnace big enough to run the whole country, say the inventors of this fantastic system for generating electrical power.

By FRANK A. TINKER



THEY MIGHT BE FIELDS of corn or wheat stretching for miles as far as the eye can see—but they aren't. In a bold new scheme to harness the sun's energy, these seemingly endless fields would be "solar farms" planted with heat-trapping devices to "grow" electrical power from sunlight. Sound fantastic? Not according to a husband-and-wife team of research scientists, Dr. and Mrs. Aden B. Meinel, who have already demonstrated a pilot model of their proposed system.

What's so remarkable about the Meinel's plan is not only that it works, but that it could be put into large-scale operation relatively quickly—a vital point in view of the desperate power crisis we now face. Those blackouts and brownouts are no accident. The fact is, we—along with the rest of the world—are simply running out of power sources. Oilmen estimate there are enough petroleum reserves to last only 11 years. Coal, though abundant, is costly to

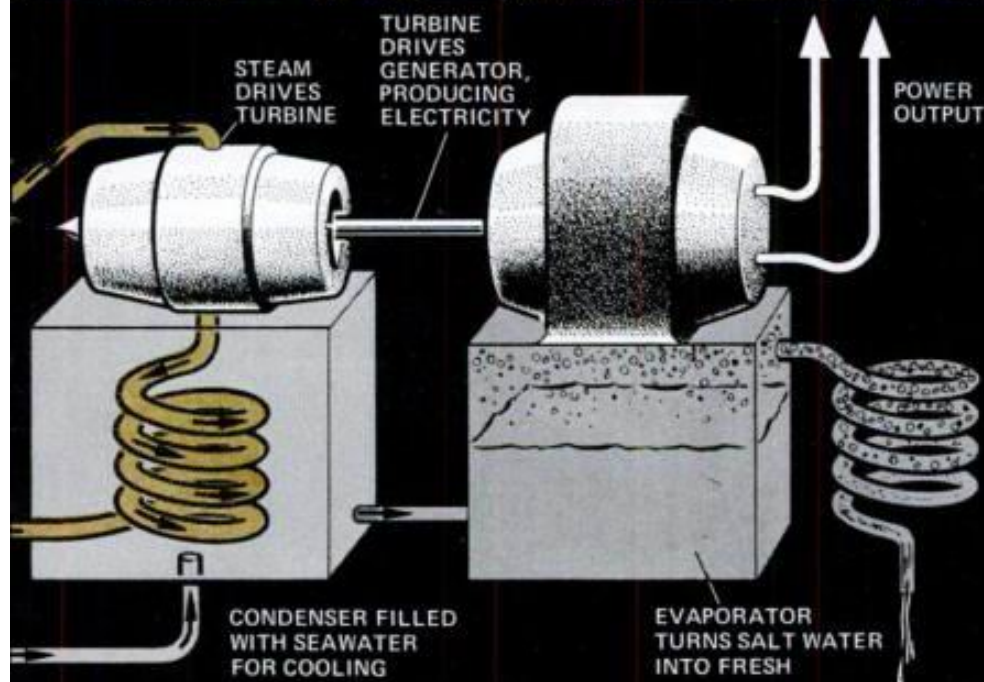
mine and a major polluter. Nuclear reactors of the size and type needed to produce meaningful power are a long way off.

That leaves the sun—cheap, plentiful and pollution-free. Doctor Meinel, director of the Optical Sciences Center at Arizona University, and his wife, Marjorie, based their system on the heat-trapping ability of microthin layers of gold, hafnium, quartz and other minerals and elements bonded together in sandwich-like panels. The panels work something like a greenhouse, letting solar heat in, then keeping it from escaping. Sunlight is absorbed by the panels, then the infrared portion is trapped inside by the reflective gold or other metallic layers. These imprisoned infrared rays build up intense heat, reaching temperatures of 1000° F.

Each panel is about 3 feet wide by 10 feet long and is angled to catch the sun's rays. A "booster" mirror is attached at a

(Please turn to page 184)

INVENTORS DR. AND MRS. MEINEL examine tiny sample of solar panel at right



HOW SOLAR HEAT is transformed into electrical power is shown in drawing at left. Literally hundreds of sloping panels catch sun's rays, heating special NAK liquid of sodium and potassium. This, in turn, heats water to create steam to drive turbine that runs generator to produce electricity. In process, seawater for cooling is turned into valuable fresh water

METAL (GOLD, HAFNIUM)
1 MILLIONTH INCH THICK

CROSS SECTION OF LAYERED HEAT-TRAP PANEL

QUARTZ

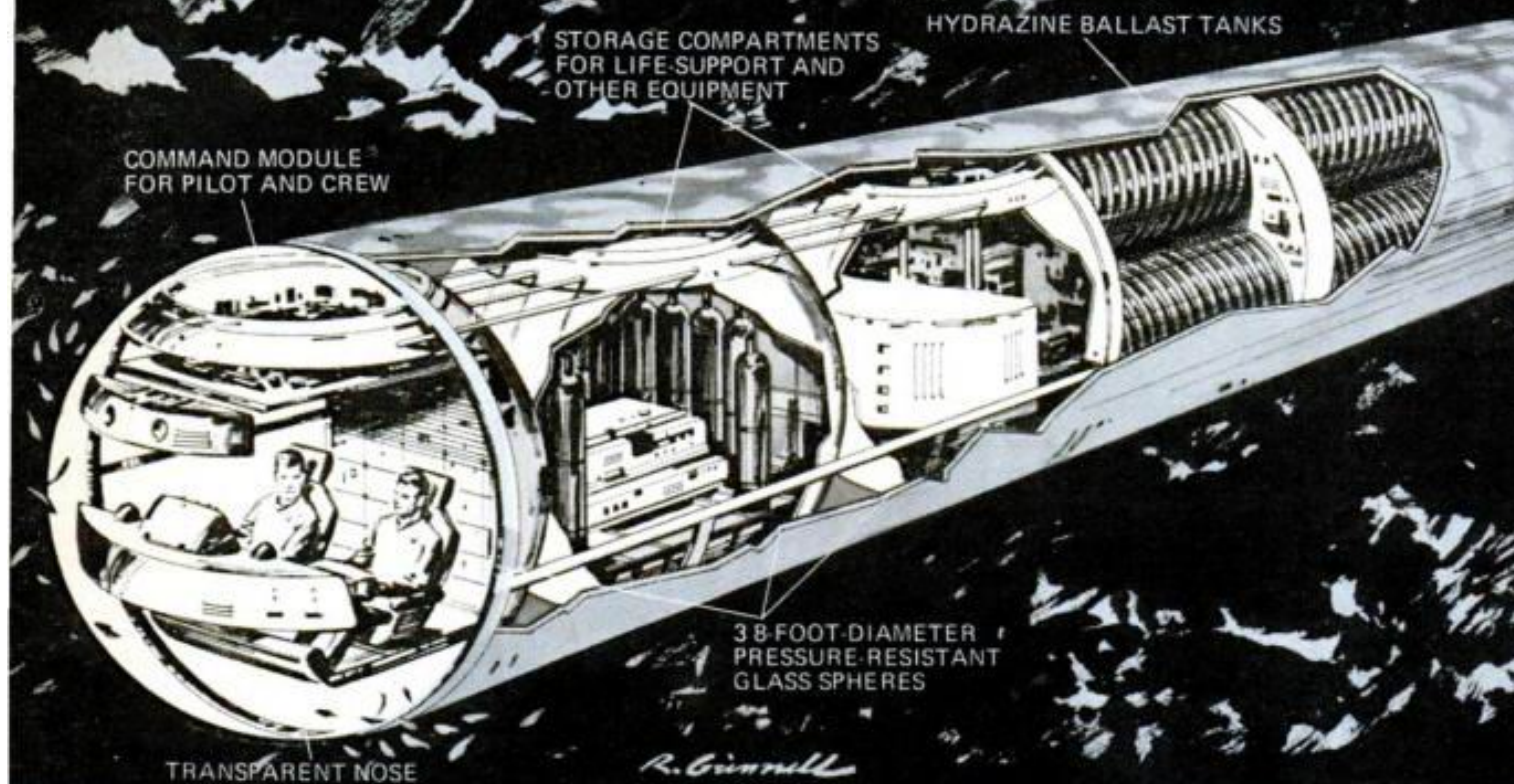
METAL

QUARTZ

Motorless sub to 'fly' the

If you can glide through air, you can glide through water. A motorless submarine designed to do just that is currently under study at the Oceanic Institute at Makapuu, Hawaii. It's 72 feet long, has stubby wings and sports an airplane-like tail. It contains no engines except for two small wingtip propellers used only for docking maneuvers. At

the beginning of the "flight," the pilot takes on seawater ballast to make the sub slightly nose-heavy. The craft then glides slowly toward the bottom, reaching depths of up to 20,000 feet. At the bottom, the ballast is blown out and gas released from pressurized hydrazine tanks to make the sub buoyant. It then glides back up to the surface,



Backpack rolls like a wheelbarrow

Why carry a heavy pack on your back when you can roll it on the ground? That's the idea behind this clever convertible pack carrier designed to ease your burden on long camping hikes. On smooth, level terrain, you simply push it along like a wheelbarrow on a small wheel mounted in a

V-shaped extension on the tubular aluminum frame. When the going gets tough on steep grades or through heavy brush, you remove the quick-release wheel and slip carrying straps over your shoulders. The two-way carrier was devised by Lee, Jesse and David Tracy of Ogden, Utah.

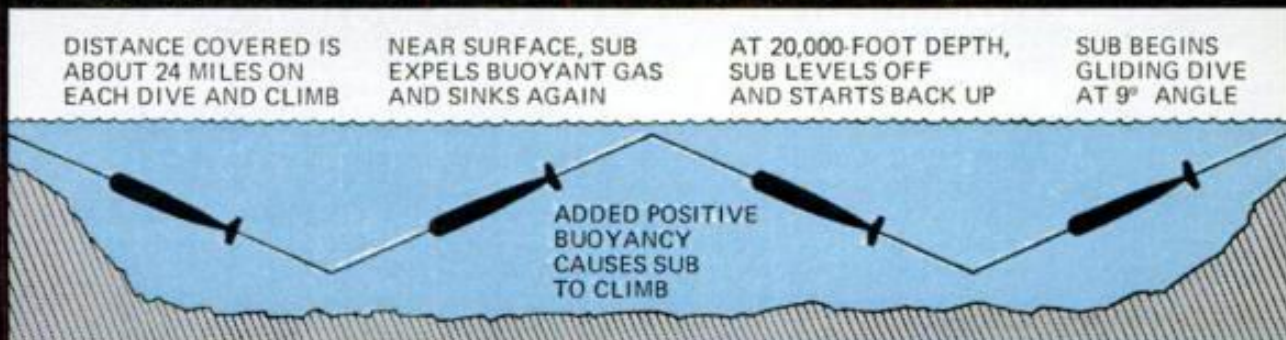


ocean like a glider

JUST PATENTED



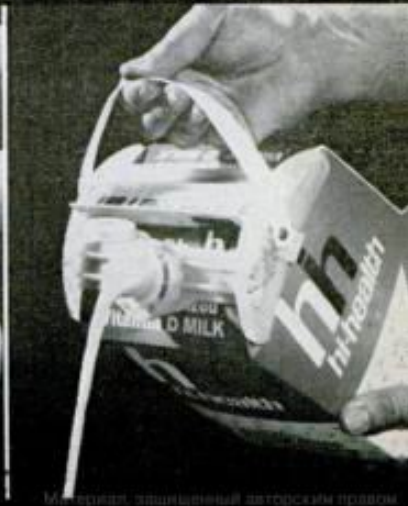
and the process is repeated. At this rate, it could travel 24 miles during each dive and climb, covering the distance from Hawaii to the West Coast in 16 days. Because it will be subjected to tremendous pressures at great depths, its main crew and equipment chambers are in the form of three glass spheres with 4-inch-thick walls. Behind these are the hydrazine gas tanks in a fiberglass hull. Air can't be used for buoyancy because, at 20,000 feet, it weighs as much as water and would provide no upward lift. The sub was designed for the Institute by engineer Willis R. Forman who believes the design can eventually make possible low-cost intercontinental transportation.



No-spill spout for a milk carton

Big gallon-size milk cartons are heavy and hard to pour—but not with this handy device. It's a combination carrying handle and pouring spout that quickly attaches to any standard gallon container. It consists of two pointed plastic end pieces that slip into openings at the top of the carton and lock together (left, below). You then screw the spout into a threaded opening, and a

toothed metal ring cuts its own hole in the container as the spout is turned (center). With the spout in place, you just remove the cap and pour (right), with no danger of spilling milk or dropping the carton. When the carton is empty, the handle and spout can be transferred to a new one for reuse. It's sold for \$2.79 postpaid by E. Z. Pour Corp., Box 149, Bayonne, N. J. 07002.



Material, защищенный авторским правом

How we'll keep 'em moving

Though the harried commuter might not think so, improved methods of transportation are on the way. If you want to see for yourself, visit Washington's big show this spring.

IF IT FLIES, FLOATS OR ROLLS—and is the latest of its type—it's sure to be at Transpo 72, a huge exposition to be staged this spring. It will be a rail and rapid transit show; an automobile, truck and bus show; a ship and boat show, and an air and space show.

Transpo 72 will be held from May 27 to June 4 at Dulles International Airport, outside of Washington, D.C. One aim of the government-sponsored extravaganza is to show what can be done to untangle the traffic mess that plagues urban areas the world over. Four personal rapid transit systems—"people movers"—will be demonstrated. These systems all employ small, independently

TRANSPORTATION
TECHNOLOGY
TRANSPORT SYSTEM

INDOOR
EXHIBITS

INDOOR
EXHIBITS

FORD MOTOR
TRANSPORT
SYSTEM

INDOOR
EXHIBITS

DASHAVEYOR
TRANSPORT
SYSTEM

INDOOR
EXHIBITS

HISTORICAL
EXHIBITS

RESTAURANT

ROHR
MONORAIL

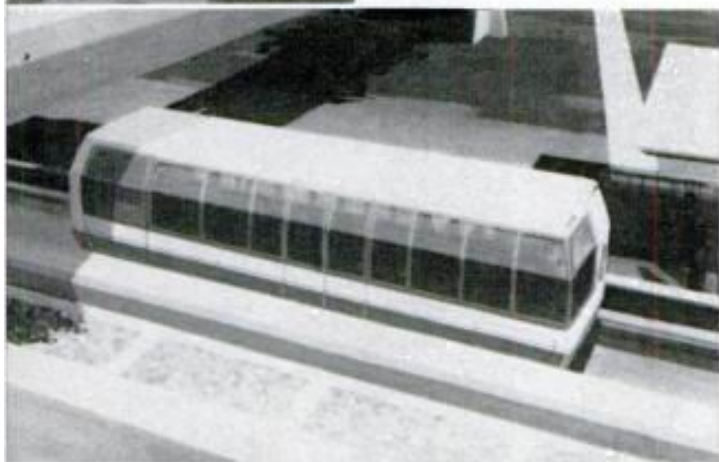
BIG EXPOSITION will require 360 acres for exhibits, demonstration areas and parking for 50,000 cars

powered vehicles that travel at relatively slow speeds on guideways and under automatic control. Flashier vehicles will include autos that drive themselves, guided by electronic devices incorporated in the highway; advanced experimental trains powered by linear induction motors and promising a capability of 300 mph; operational air-cushion vehicles and prototypes of deep-water hydrofoils.

If you're especially interested in airplanes, you'll be confronted with an imposing array, including the new McDonnell Douglas DC-10; Lockheed's C-5A, the world's largest plane; the British Harrier, now adopted by the U.S. Marine Corps, which can fly at 600 mph and also take off and land vertically. If plans work out, the SSTs will also be on hand—the British-French Concorde and the Russian Tupelov 144. There'll be antique planes, too, including the Ford Tri-Motor, Jennie, Curtiss Pusher and more.

Plenty of action is promised. Professional race pilots will zip small planes—none heavier than 550 pounds—around a course. There will be balloon races, simulated dogfights with World War I planes, and demonstrations by the Navy Blue Angels, Air Force Thunderbirds and other aerobatic teams.

According to Transpo 72 officials, the show will be open to the public from 9:00 a.m. to 6:00 p.m. on May 27, 28 and 29; from 12:00 p.m. to 6:00 p.m. on May 30, 31 and June 1, 2; from 9:00 a.m. to 6:00 p.m. on June 3, 4. Admission will be \$3 for adults and \$1 for children. ★ ★ ★



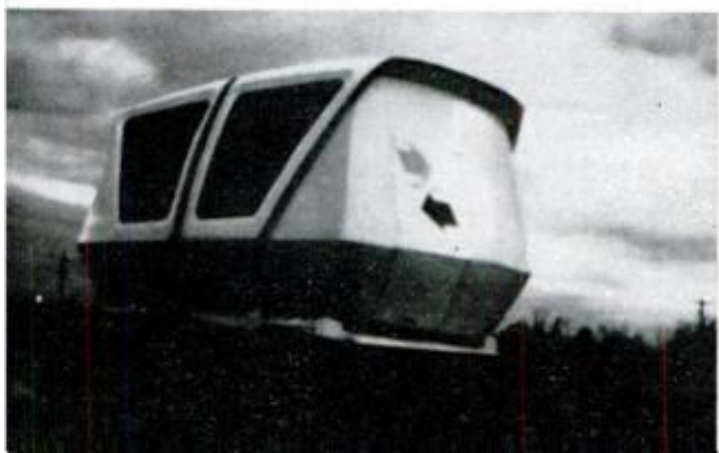
FORD MOTOR'S ENTRY in the "people mover" competition is electrically driven, 24-passenger vehicle



MONORAIL for carrying passengers at 17 mph is built by the Rohr Corp. System will have two cars

LINEAR INDUCTION MOTOR drives the Transportation Technology Co.'s car. Capacity is 6-10 persons

THIRTY-ONE PASSENGERS will ride at 20 mph in the Dashaveyor Co.'s car. Like others, it's automated



Now it's ferry trains for



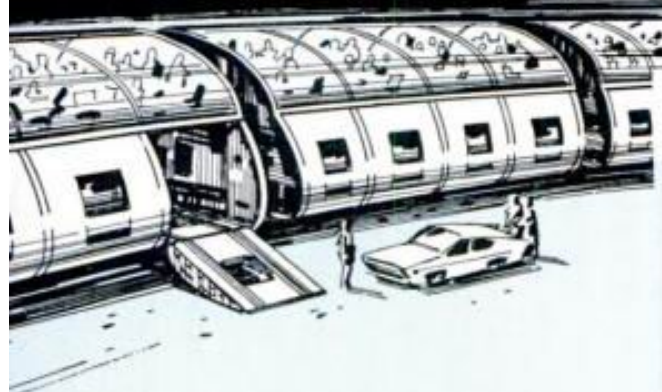
You drive your car right on board the novel ferry train above, enjoy a fast, relaxed ride to your destination, then drive off again, ready to continue your trip by road. The new concept of combined road-and-rail travel is designed to provide high-speed transportation between distant points without long and tiring highway driving, yet enable you to take your car along with you for local touring and sightseeing when you arrive. While on board the train, you can rest in your car or visit an upper-level observation deck where there are comfortable lounge chairs and snack-bar facilities. Hinged, swing-down hatches in the sides of the train form ramps so you can drive on and off easily. The idea was conceived by Veljko Milenkovic of Boulder, Colo.



Quick-release belt

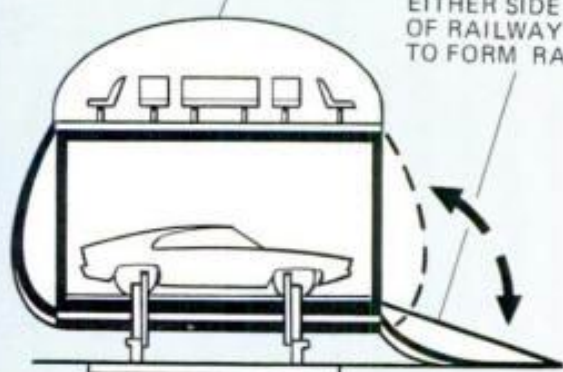
Motorists who hate to wear shoulder-type safety belts because they're so awkward to get in and out of will go for this ingenious idea. The upper end of this belt slides in a U-shaped track overhead. To put on the strap, you just swing it around the track across your shoulder until it locks into a small S-shaped bend. Reversing the process releases the belt quickly and easily without undoing the clasp. There's no need to adjust belt tension each time since the length can be preset and left alone. Inventor is John R. Hane, Box 444, Shalimar, Fla.

cars yet!



UPPER
OBSERVATION
DECK AND
LOUNGE

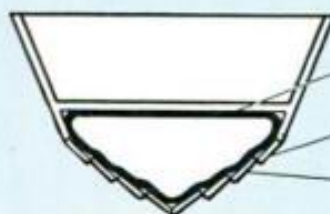
HATCH SWINGS
DOWN FROM
EITHER SIDE
OF RAILWAY CAR
TO FORM RAMP



Illustrations by Roy Grinnell



HULL FLAT FOR
HIGH-SPEED PLANING
ON CALM WATER



INFLATABLE AIRTIGHT
COMPARTMENT

HINGED SLATS WITH
FLEXIBLE LINING

HULL V-SHAPED FOR SMOOTH
RIDING IN ROUGH WATER

Self-adjusting boat hull

You want a flat planing hull for high speed on calm water, but a deep V-bottom for smooth going in rough seas. With this adjustable hull, you could have both. It consists of flexibly hinged strips with an inflatable air bag inside. As the water roughens, a motion-sensitive device automatically inflates the bag to force the strips into a V shape. Harold L. Walker, Whitestone, N. Y., is the inventor.

Electronic 'money'

No money changes hands when you fill up at this electronic gas pump. You simply insert a coded card in a slot and the pump "draws off" or erases a number of magnetic pulses equal to the number of gallons you purchased. When all the pulses are used up, you take the card back to your bank and have it "recharged." The pump totals up the pulses "taken in" each day and records them on a card the garage owner can convert into cash at his bank. The system, now in use at some British gas stations, is being considered for restaurants, supermarkets and other stores. It was devised by Bernard Hunn, Revenue Systems, Luton, England.

FEBRUARY 1972



Train of the Future: 400 MPH on

HIGH-SPEED TRAINS encounter one big problem: The faster they go, the more air pressure builds up in front and the more power is required to overcome the resistance. Eventually, the resistance mounts up to a point where it acts, in effect, as a wall. In the new system shown here, bulletlike cars are driven by steam through an underground tube—like a piston in a cylinder. The tube is filled with water vapor that replaces the air without the need for costly vacuum pumps. As the cars accelerate, pressure causes the vapor to condense on the walls of the tube, leaving virtually a clear vacuum ahead. Speeds up to 400 mph or more are possible on a single blast of steam, and the train can coast for several hundred miles without slowing appreciably. At each stop, a new blast of steam sends the train on its way again. The ingenious plan, designed for long-distance, high-speed travel, is under study by Susquehanna Corp. of Alexandria, Va.

UNDERGROUND TUBE UNAFFECTED BY
SURFACE STORMS, HEAVY TRAFFIC
OR OTHER LOCAL DISTURBANCES

EACH CAR HOLDS UP
TO 160 PASSENGERS

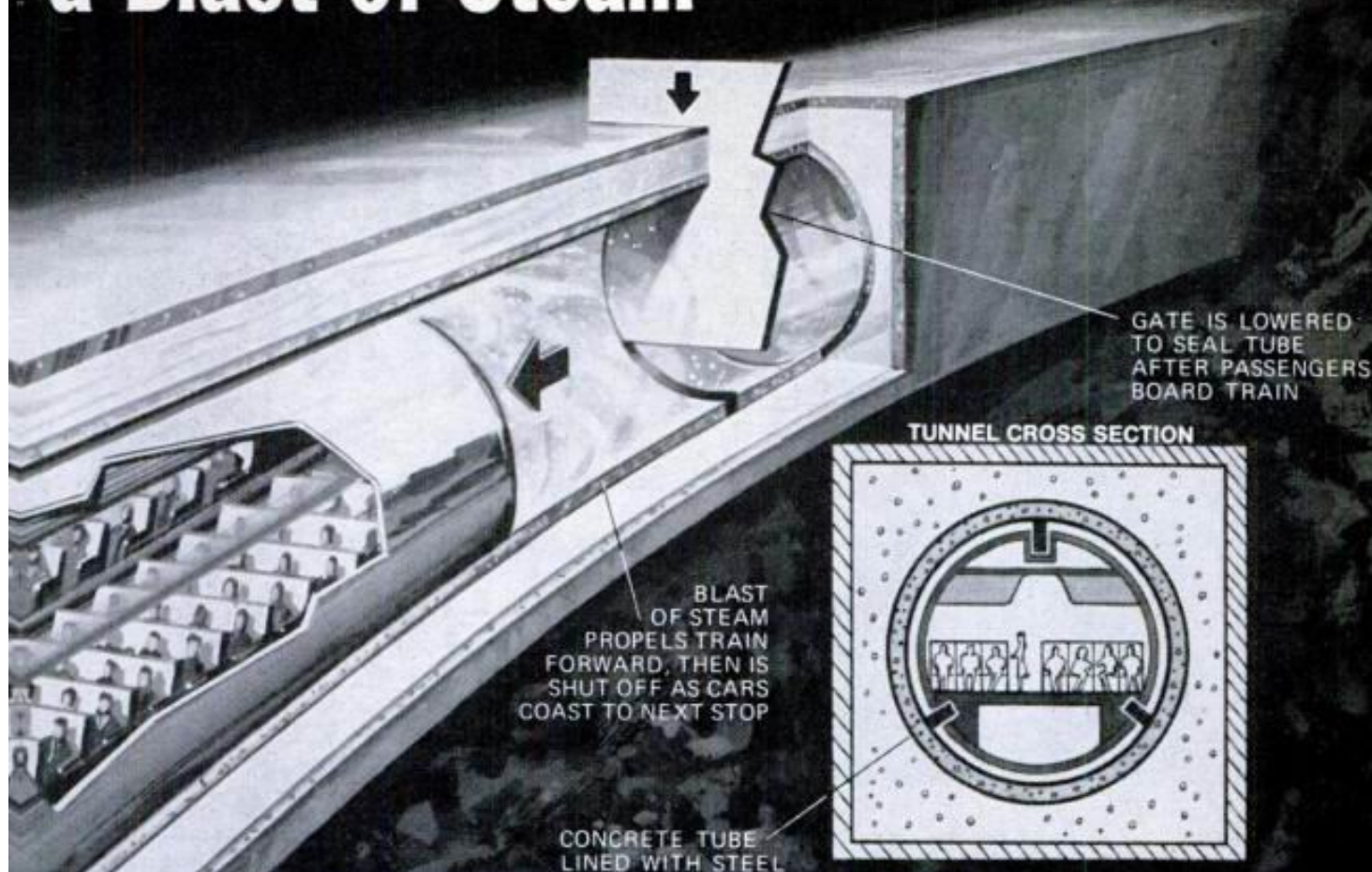
WATER VAPOR CONDENSES AHEAD
OF TRAIN, ELIMINATING RESISTANCE

RUBBER TIERED
WHEELS RIDE
IN GUIDE
SLOTS TO KEEP
TRAIN LEVEL

Illustrations by Roy Grinnell

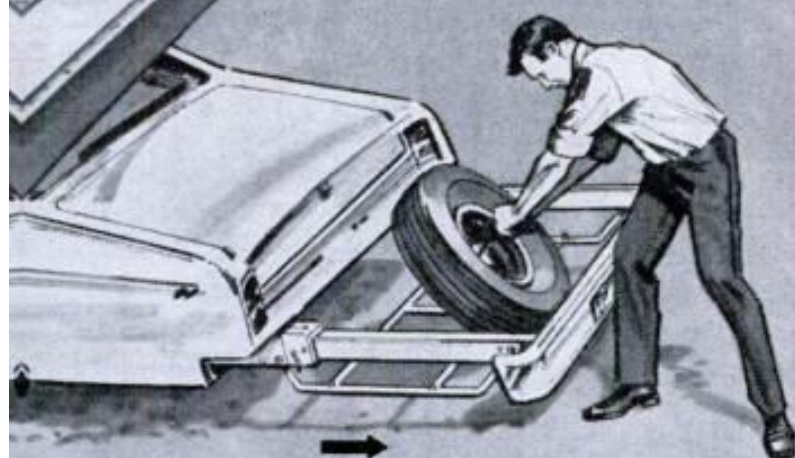
a Blast of Steam

PRICE \$1,000
JUST PATENTED



Quick-Change Slide-Out Spare

Your spare tire is usually buried at the bottom of a trunkful of luggage when you suddenly need it on a trip—but not this one. You simply slide out the rear bumper and with it comes the spare held neatly in a telescoping rack. Your jack, a lug wrench and other tools can also be stored in the rack for easier access. The inventor is William T. Woods of Bertrand, Mo.



Handy Indoor Garbage Disposer

You don't have to go outdoors to get rid of the garbage with this convenient through-the-wall disposal system. You just open a door, toss in your bags of waste, and they slide down a chute directly into a pail placed outside. For emptying the pail, the hinged chute swings up, lifting the lid with it. Invented by George O. Mullens of Gardena, Calif., the chute arrangement will also prevent animals from getting at the garbage.



How to Carve a Mountain

By JAMES M. LISTON, Executive Editor

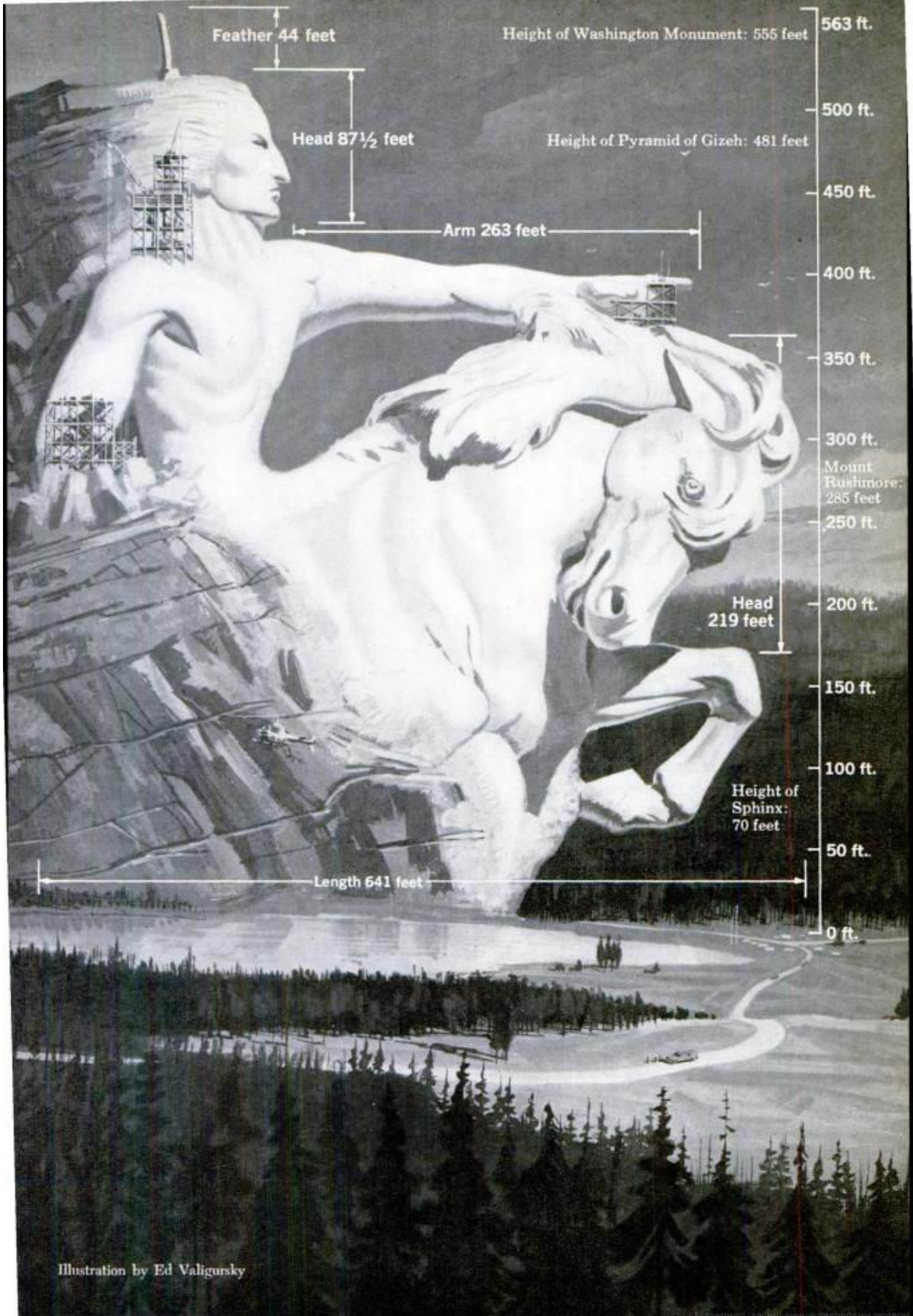
THE HEROIC SIZE of the Indian astride his war pony staggers the imagination. Shown here as it will appear if completed on schedule in 1979, the mountain memorial to Sioux Chief Crazy Horse, who defeated General Custer in the Battle of the Little Big Horn, will be taller than the Washington Monument—four Rushmores would fit on it—and bigger than the largest Egyptian pyramid. It may become the eighth wonder of the world and certainly the most enduring. The granite from which it is being carved will last some 50,000 years.

To most tourists, South Dakota is best known for the faces of the four presidents at Mount Rushmore. Yet only 20 minutes away over the Hearst Highway near Custer you

(Text continues on page 78)

CHIEF CRAZY HORSE, pointing to the lands of his people, will be the focal point of the complete project—an Indian cultural center consisting of a university, medical school and museum where Indian traditions and crafts will be preserved. Sculptor Korczak Ziolkowski hopes that through admissions and contributions the mountain carving will create and maintain the center as a gift to the North American Indian, "a people who have given us so much." To insure that the center will not be forgotten—and the memorial become nothing more than a tourist attraction—Ziolkowski has transferred ownership to a private foundation.





Feather 44 feet

Height of Washington Monument: 555 feet

563 ft.

Head $87\frac{1}{2}$ feet

Height of Pyramid of Gizeh: 481 feet

500 ft.

Arm 263 feet

450 ft.

400 ft.

350 ft.

300 ft.

Mount
Rushmore:
285 feet

250 ft.

Head
219 feet

200 ft.

150 ft.

Height of
Sphinx:
70 feet

100 ft.

50 ft.

Length 641 feet

0 ft.



DRILLING PROGRESS: In the early '50s, Ziolkowski and a hired man were "leaning" on 115-p.s.i. jackhammers (left) to average 40 feet a day. Twelve years later, he hauled a wagon drill up the mountain and boosted rate to 200 feet a day. Sculptor's sons now operate self-propelled Air-Trac rig (right) at rate of a foot a minute

can see Crazy Horse being carved in the round—in three dimensions; Rushmore's figures are in bold relief—and witness history being made. Last year 300,000 visited Crazy Horse Memorial.

The sheer magnitude of the job is exceeded only by the daring of the man who chose to gamble the best years of his life and his enormous talent against the possibility of creating a lasting monument to his own failure. Korczak Ziolkowski ("Core-shock Jewel-cuff-ski"), sculptor and—more aptly at this stage—engineer, has been battling the mountain for 22 years. Now 61, he would like to live to 70 to complete it.

You have to know the man to believe it's possible. I've known Korczak most of those 22 years. Back in 1953 he had two jackhammers going; I tried my hand at one and was convinced that no one could drill 150,000 holes 20-30 feet deep that way in 30 years. He described in detail the kind of big equipment he'd need and it was little wonder that his neighbors in the Hills called him a dreamer. One thing kept me from joining the skeptics: Nothing awed this super do-it-yourself man, whether it was building a house, moving a 13-ton compressor, handling high voltage wires, or delivering his own child. If it could be done, he'd do it.

Ziolkowski has removed 2,560,000

tons of rock, seven times more than was removed from Rushmore. It took Gutzon Borglum, with a crew of 20 and \$989,992 of federal and private funds, 14 years to complete Rushmore. Except for an occasional helper, and recently with the help of his five sons (aged 10 to 22), Korczak has done it pretty much alone. He has spent more than \$1 million for dynamite and equipment—all of it from \$2-a-car admissions and private contributions. The biggest job remains; he must remove another 3.5 million tons—and he aims to do it by the end of this decade.

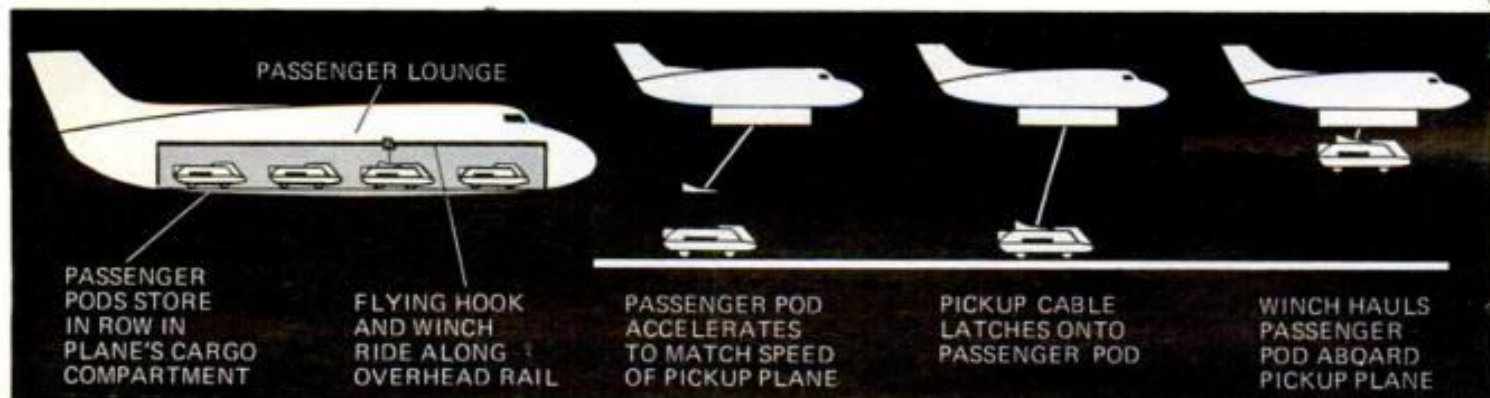
Ziolkowski, a self-taught sculptor (he's never had an art lesson) whose bust of Polish premier-pianist Ignace

TUNNEL under Indian's arm is 182 feet long, 14 feet high. Eventually, it will be a 106-foot-high gap



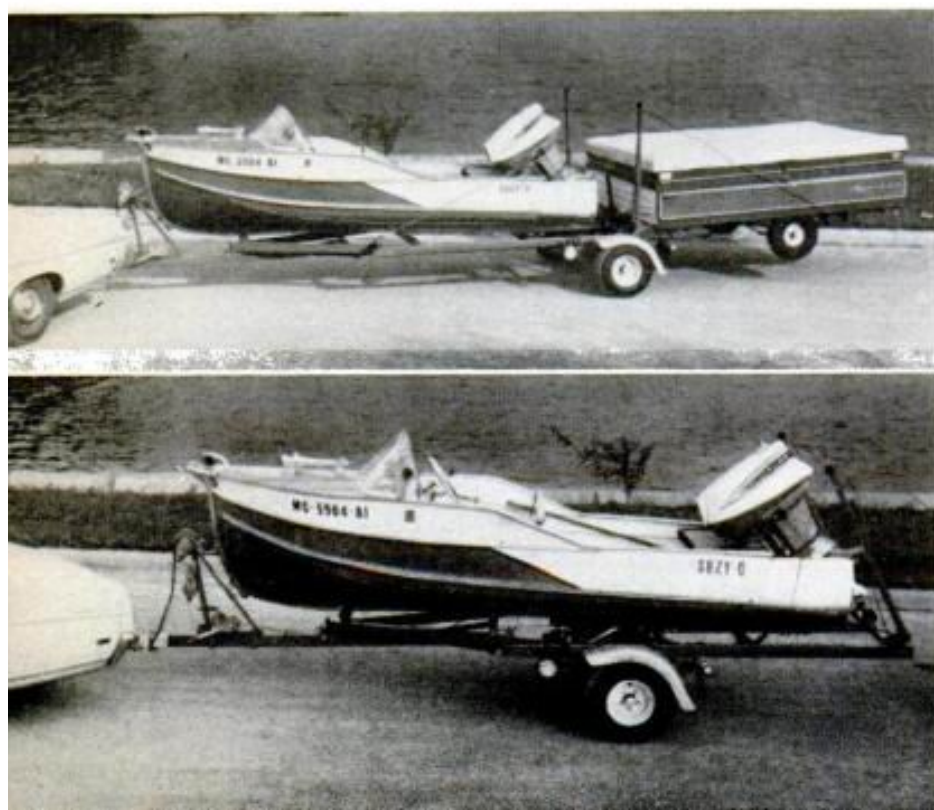
JUST PATENTED

This airliner never lands -it hauls you up instead!



Double totter

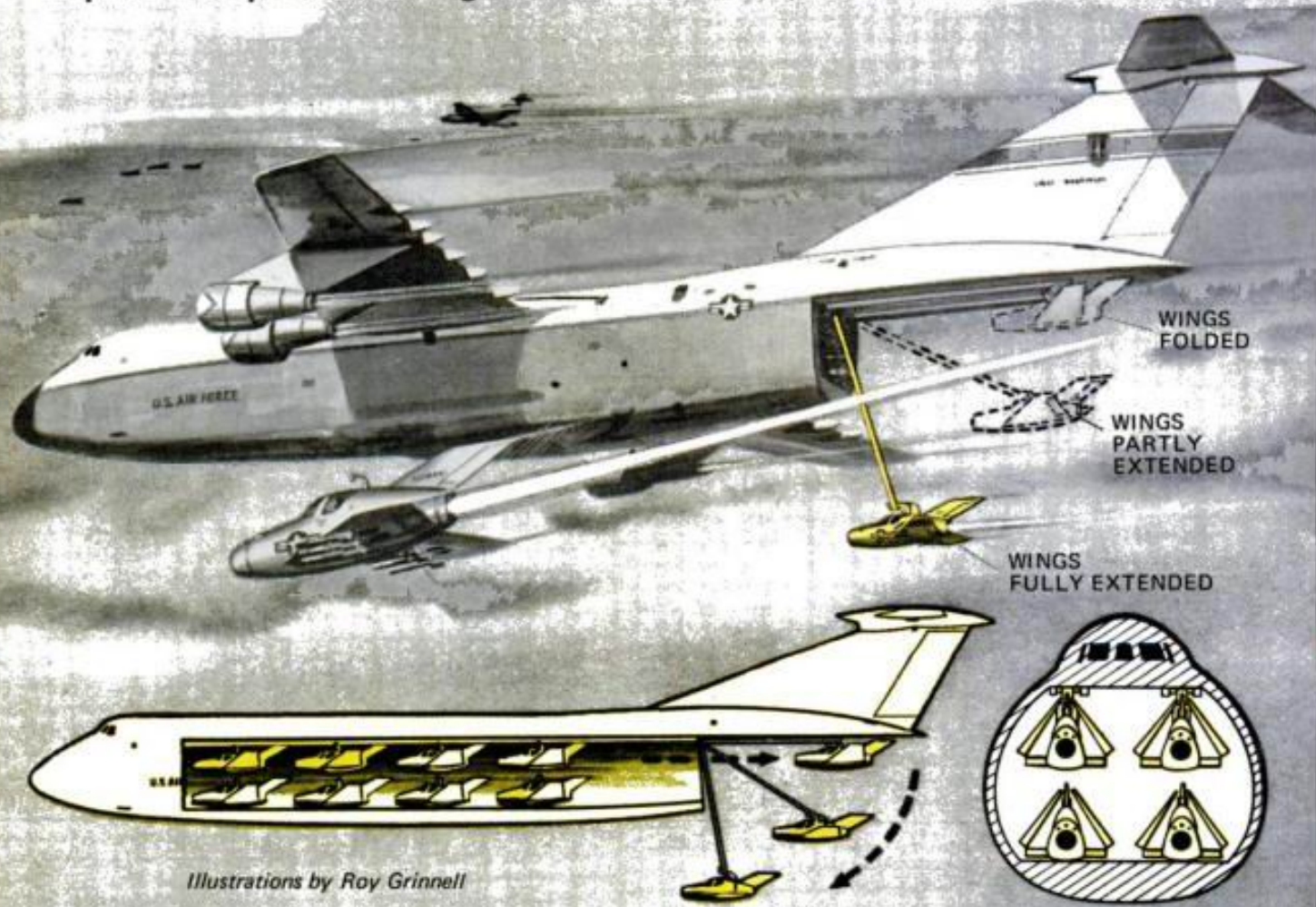
You can haul both a boat and a camp trailer with this piggy-back rig. The camp trailer locks into supports at the rear of the boat trailer and is raised off the ground by cables so its wheels won't drag. At the same time, the boat trailer's wheels are moved farther back to provide a better balance point for the combined load (upper photo at left). For trailering the boat alone, the wheels are moved forward to their normal position (lower photo). The inventor is Glenn Black, 1007 Wilson St., Bay City, Mich.



Just patented

PM'S PICK OF THE NEW INVENTIONS

Prepared in cooperation with Roger S. Shashoua, Director, International Inventors Assn., Inc.



Illustrations by Roy Grinnell

1. FLYING "FLATTOP" can launch fighter planes or small bombers at a moment's notice. The planes, with wings folded, are held in overhead tracks inside the huge cargo compartment. One by one, they slide along the tracks onto a pivoted boom at the tail. The boom swings down, carrying each plane below the mother ship. The wings unfold, the boom

hook is released and the plane flies off under its own power. The flying carrier could get the planes where they're needed much faster than conventional oceangoing aircraft carriers and would be less vulnerable to enemy attack. Returning planes could be picked up by the mother ship through techniques similar to those in use today in midair refueling

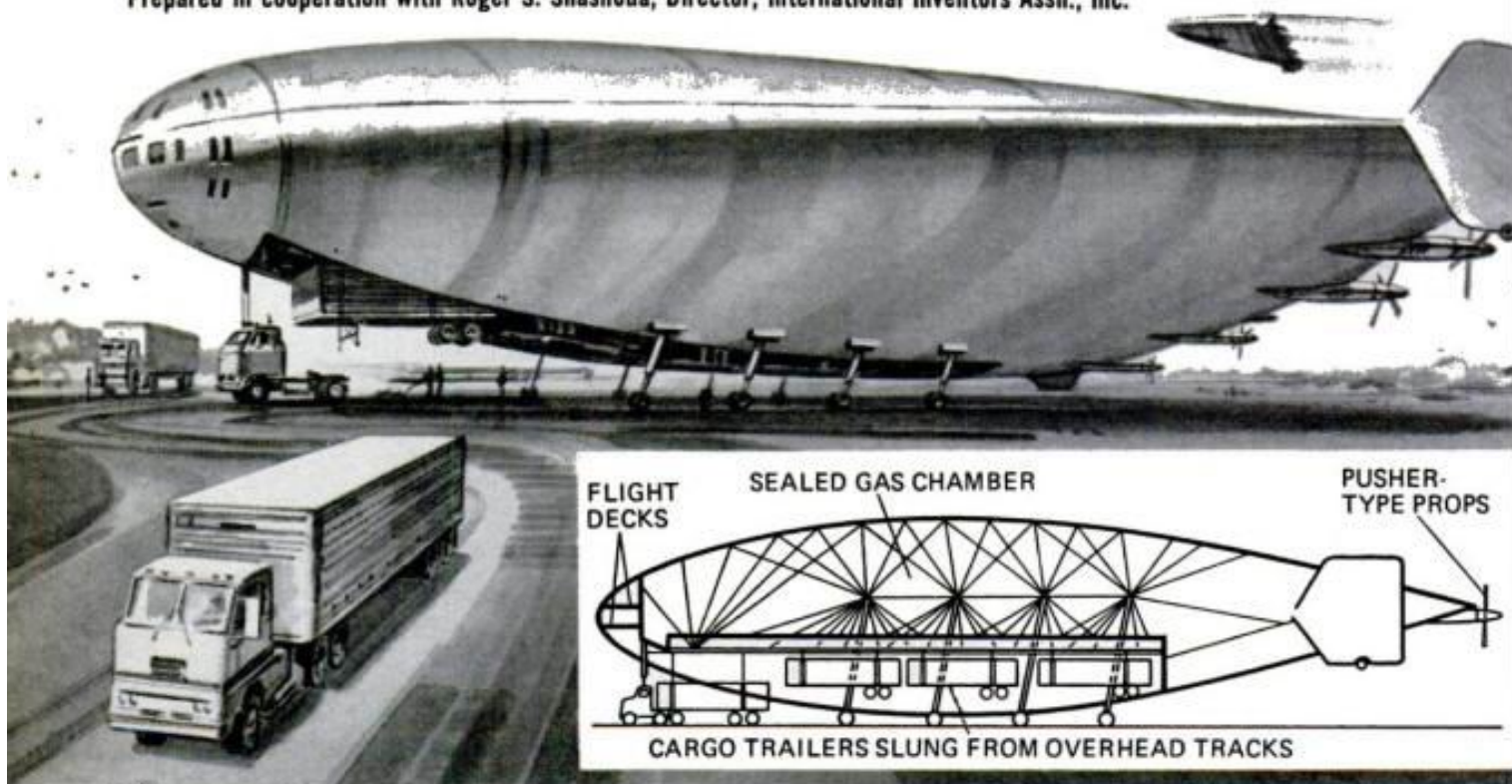


2. EMERGENCY POP-UP FLARE can be released the instant you pull to the side of a road, indicating to passing motorists that your car is disabled. An ordinary road flare is held in the end of a long spring-loaded mast. In its stored position, the mast lies flat along the rear bumper. When you press a button on the dashboard, it heats up a small coil pressed against the end of the flare like a cigaret lighter. This ignites the flare and the heat releases a bimetallic catch, allowing the mast to spring upward into a vertical position to warn other cars of the roadside danger

Just patented

PM'S PICK OF THE NEW INVENTIONS

Prepared in cooperation with Roger S. Shashoua, Director, International Inventors Assn., Inc.

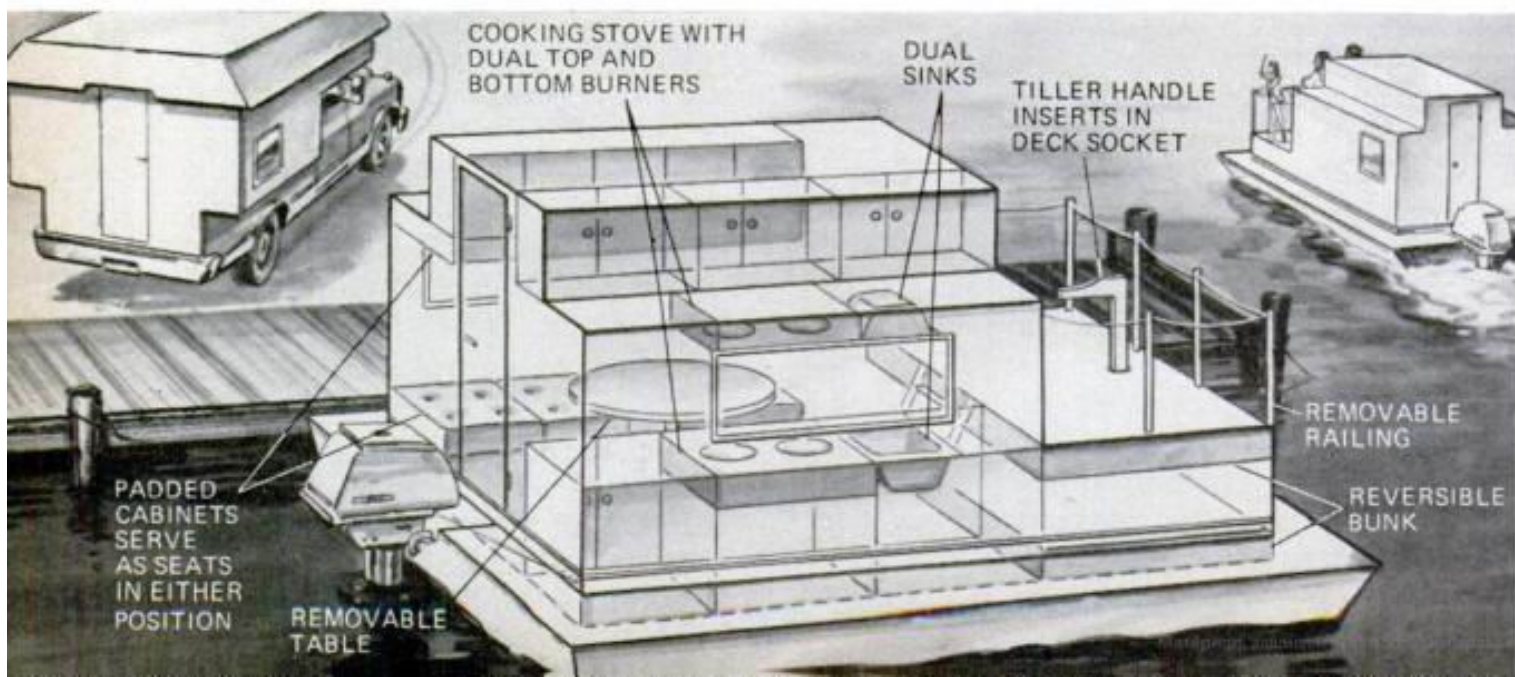


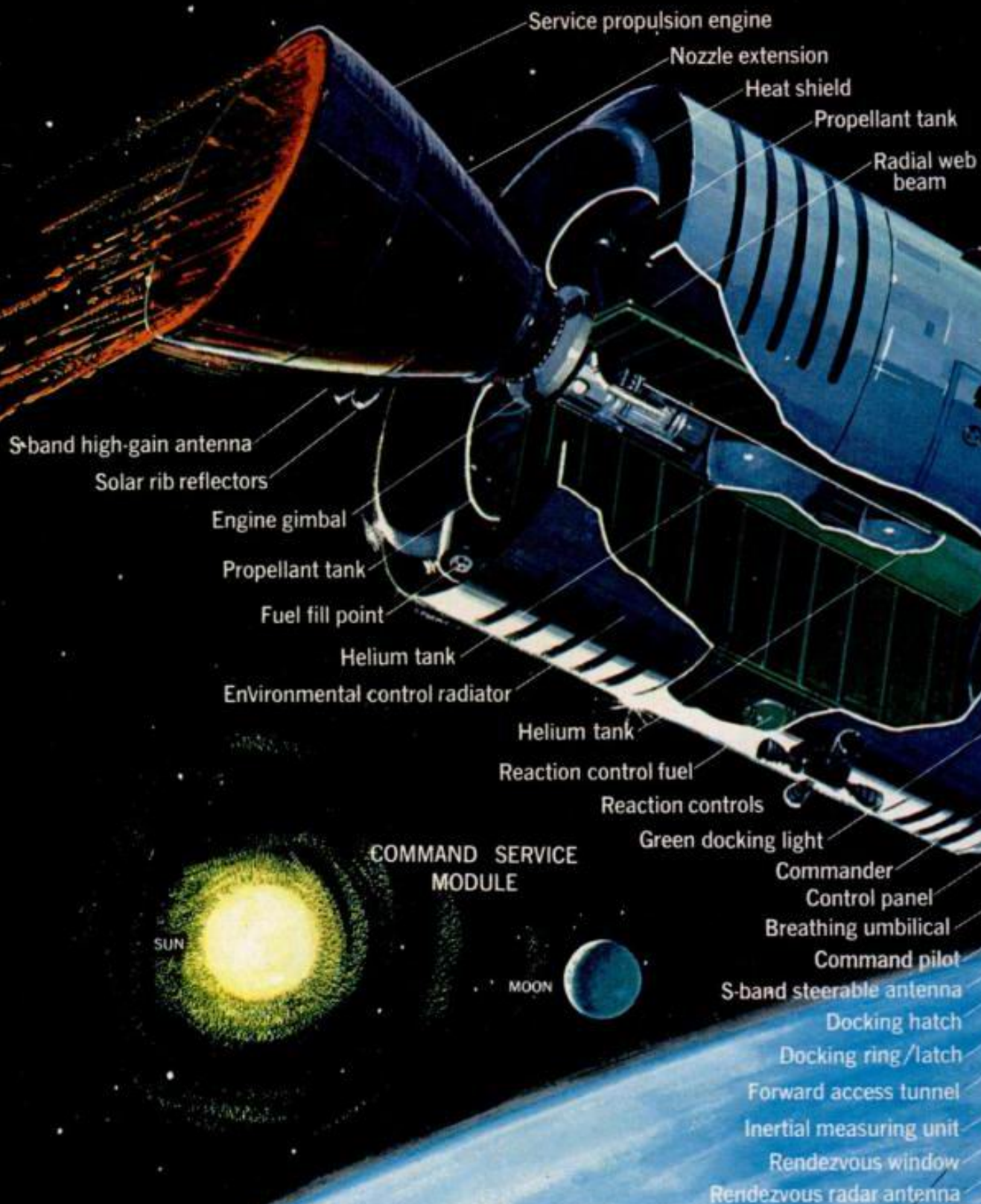
1. HALF AIRPLANE, HALF DIRIGIBLE, this monster hybrid is designed to combine the advantages of both. The rigid, wing-shaped fuselage has the speed of an airplane, but gets added lift from a gas-filled chamber, enabling it to carry many times more cargo weight. Huge cargo trailers are backed under

the loading doors and hoisted by cranes onto overhead tracks for fast transportation to distant points. At the landing site, tractor units pick up the trailers for delivery to local destinations, thus saving long hours of road travel. The giant ship is powered by pusher props along the trailing edge

2. JUST FLIP IT OVER and this two-way pickup camper becomes a small outboard-powered houseboat so you can enjoy vacation travels on either land or water. The camper's slope-sided roof doubles as a shallow hull when the structure is inverted. Inside, duplicate rows of built-ins serve as overhead

cupboards or seats and bunks, depending on which is on top. Twin sink and cooking facilities can be used in either position, and a removable table fits into a socket in the floor or roof. Hydraulic jacks are used to tip the camper body out of the pickup, like a dump truck, for launching in water





Command Service Module emerges from shroud using vernier rockets



CSM turns around to nose in toward Lunar Module



CSM mates with LEM



and both move away from third stage booster

With LEM attached, CSM uses main rocket



to move into proper orbit

APOLLO SPACECRAFT

Astronauts in first transfer from Command Module to Lunar Module in test flight while in Earth orbit.



VHF omni antenna

Fly away umbilical

Red docking light

Command module, service module fairing

Electrical-power
system radiator

Aft heat shield

Yaw motor

Side window

Crew access hatch

Rendezvous
window

LUNAR MODULE
(Ascent Stage)

VHF inflight antenna

Aft equipment bay

Reaction control thrusters

Docking guide

Oxidizer tank

Helium tank

Environmental controls

Fuel tank

Ascent engine

Radioisotope
thermal
generators

Scientific
equipment

LM pilot

Visual lunar
landing grid

S-band
antenna

Reaction control
thrusters

Ingress-egress
hatch

Platform and railing

LUNAR MODULE
(Descent Stage)

Specimen return box

S-band erectable antenna

Descent ladder

Primary strut

Landing pad

Descent
engine skirt

Illustration created especially for Popular Mechanics by Fred Wertz, Ed Valigursky and Marian Manfredi

IT STROLLS, CLIMBS, BALANCES The Fabulous

This strange beast of burden—produced by GE, sired by the Army—goes places wheels can't

If you've been thinking of multiwheel or track-laying vehicles as the ultimate in go-anywhere transportation, you may have to change your mind.

This truck on legs promises to walk to places that are inaccessible to conventional off-the-road vehicles. It was born when a group of scientists went right back to basics, and chose as their point of departure the fact that the wheel does not appear anywhere in nature—it's a man-made device, and it may be that nature has more effective forms of mobility for really tough going.

The 3,000-pound walking truck indicates that they may be right. It can balance on two legs, and it can walk over and around large obstacles. It can walk

forward and backward, and it can turn around. Top speed is five m.p.h. It can carry a 500-pound payload, and lift loads up to 500 pounds with one foot. It can drag a 1,000-pound load across a floor.

The power unit is a 90-hp. gasoline engine that drives a pump for a high-pressure hydraulic system. The legs are moved by hydraulic actuators with an oil flow of 50 gallons per minute at 2,400 pounds per square inch.

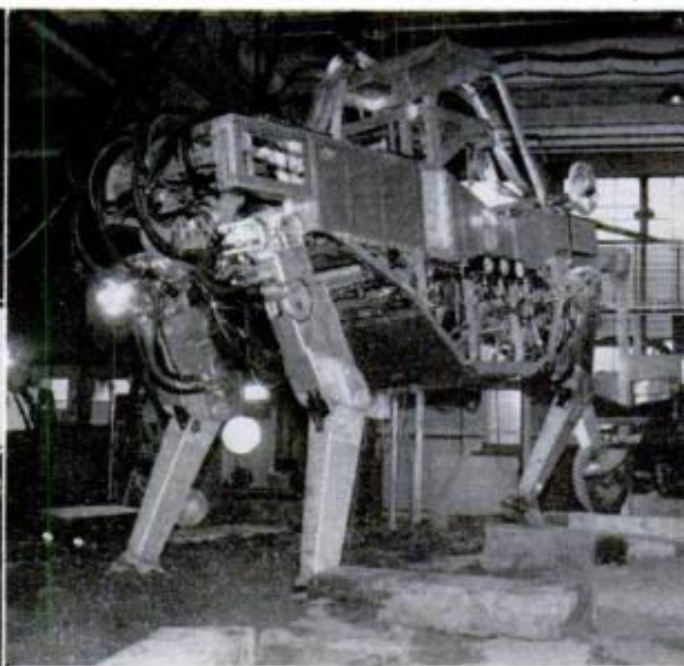
The actuator servos are hydromechanical and need no electronic elements. They work two ways, taking orders from the controls via the master actuator, and feeding back to the operator. The feedback tells the operator something about the force he is using to walk the truck, and enables him to make adjustments in handling the controls.

How do you "drive" it? A tractor-type seat leaves both arms and legs free to drive the truck. The seat is adjustable fore and aft, up and down, and for tilt

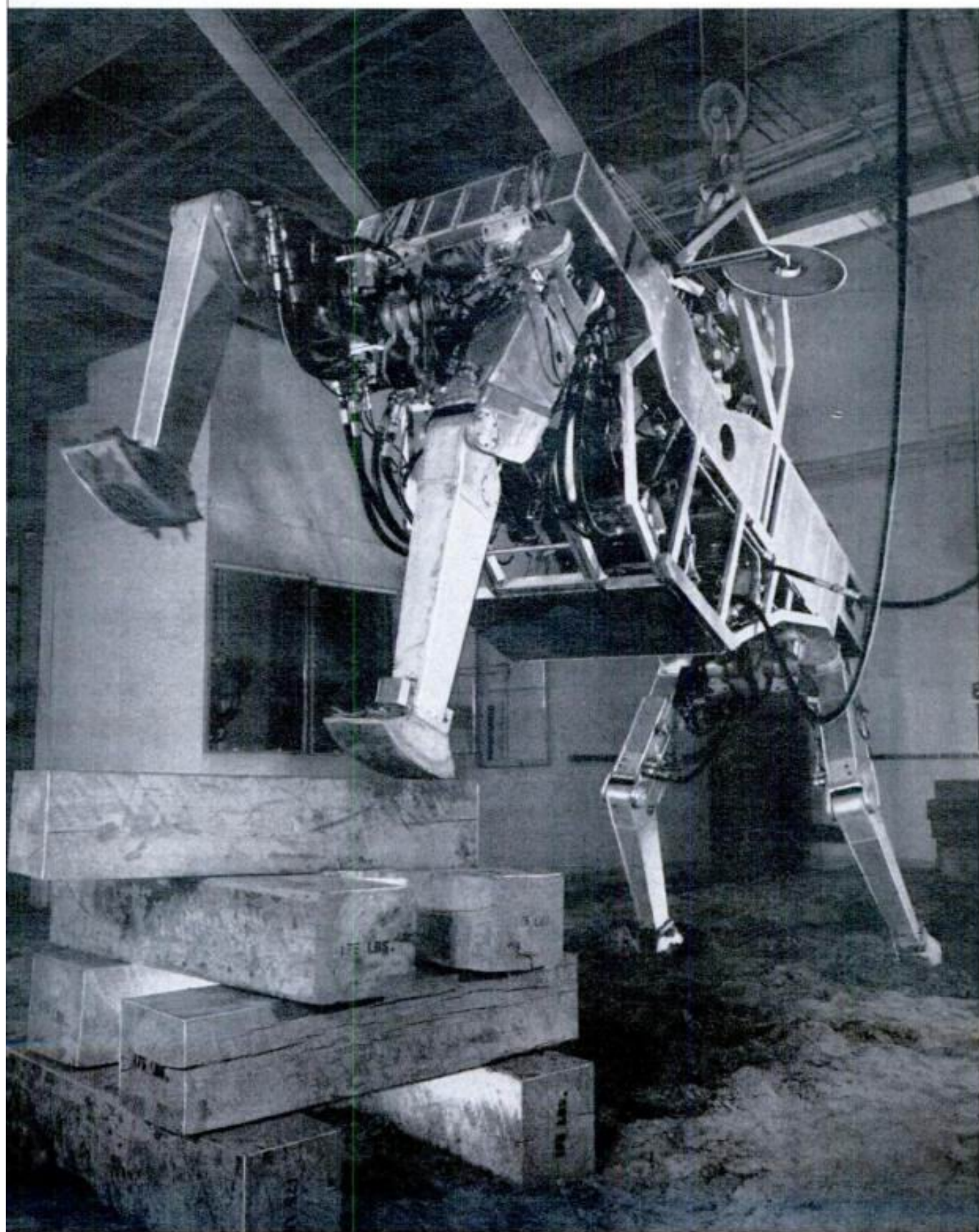
Continued

Operator sits in a cage-like cabin on top of the truck, with his head about 15 feet off the ground. Both his arms and both legs are in continuous use when the truck is walking; the truck legs simply mimic, in amplified form, the limb motions of the operator.

Engine and pump are held in the belly of the truck, with hydraulic pipes running to actuators in each leg for hip and knee joints. In photo at right, the truck is seen climbing a wood log stand with right-front foot and left-rear foot in the air simultaneously.



ON TWO LEGS- **Walking Truck**



The beginner's worst control problem? He can't see the rear legs

angle, like a six-way passenger-car seat.

Your arms direct the front legs of the truck, and your legs control the rear legs. Your movements are amplified four times,

and your strength is limited only by the pressure in the hydraulic system. Each leg has a hip joint, thigh, knee joint, and a lower section that includes the foot. There are no ankle joints.

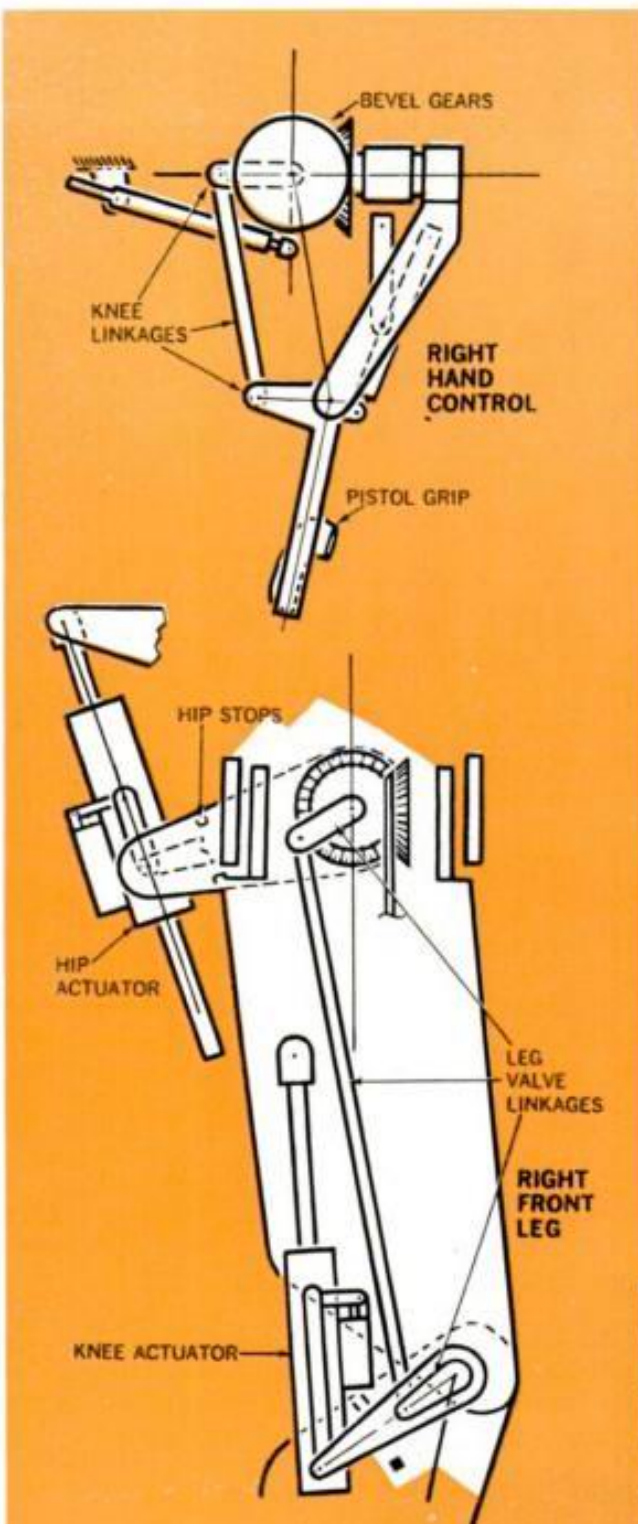
The hydraulic actuators induce motions in the truck legs that correspond to the motions of the control elements—i.e., your handgrips and pedals. The controls pick up both position and force, and the actuators respond accordingly. The machine becomes almost a rational extension of the driver, and responds to his natural, complex, neuromuscular reflexes in a simplified manner.

The hip joints have two motions (fore and aft, and sideways), while the knee joint allows only fore-and-aft motions. The hip joint allows the thigh to swing 70 degrees forward and 20 degrees backward. Mechanical stops prevent further movement. The foot can exert a force of 1,500 pounds in any direction, and even much higher forces in some cases, depending on the leg-linkage position.

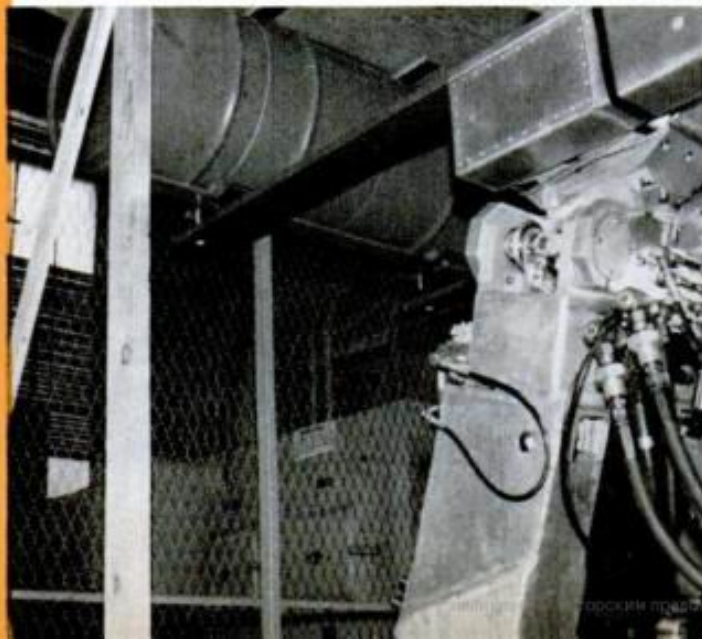
The hand controls end in a pistol grip. You twist, pull, push, lift, or lower the handles, and the front legs on the truck mimic your motions.

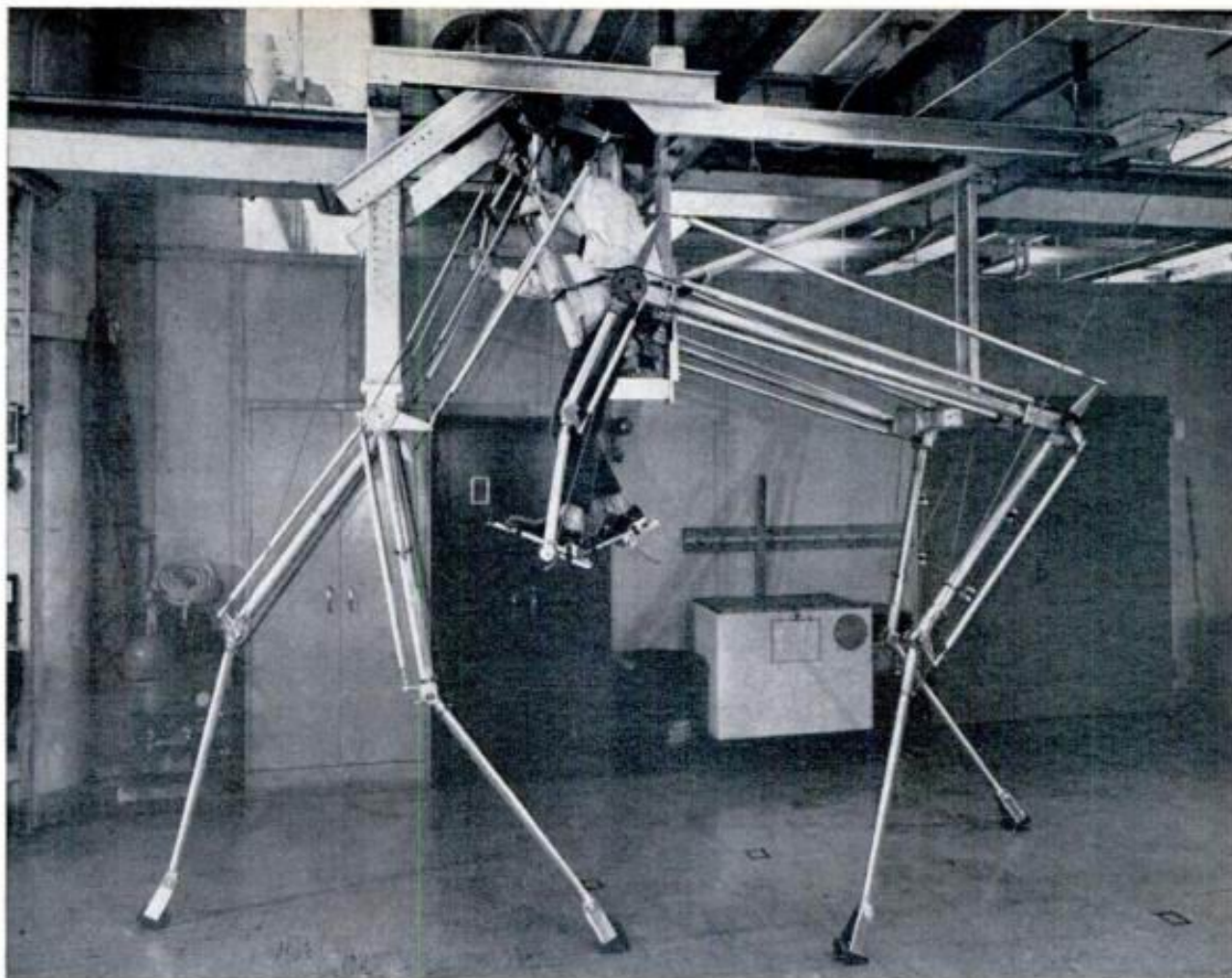
The pedals are really shoe pads strapped to the driver's boots before he enters the vehicle.

Keeping your balance. Since your head is some 15 feet off the ground, you may be a little overcautious about lifting more than one leg at a time. But the truck will balance on two legs, and the learning process is really not a matter of skill but of developing a mental attitude. You already know how to walk, and since all



Hip joints can turn both sideways and in a fore-and-aft plane; knee joints, however, move only fore-and-aft. A mechanical linkage coordinates hip- and knee-joint motions in each leg, and mechanical stops limit angularity. At right, the walking truck is shown picking up a simulated bomb for loading into an airplane. This exercise shows the machine's ability to move with precision in performing practical tasks where working space is limited.





A full-scale nonpowered quadruped was built and tested as a feasibility study for the truck's control

system. It is supported and moved back and forth by an overhead crane, but kinematics are realistic.

the machine does is put your natural body movements into the truck legs, you know how to handle the walking part. The truck takes its cues from your motions.

The only real difficulty the test drivers at General Electric have found (GE developed the walking truck under contracts with the U.S. Army Tank Automotive Command and the Advanced Research Projects Agency) is sensing and responding to tail-end and rear-leg motions. These parts are out of the operator's sight, and he has a hard time interpreting pitch and yaw action. The test drivers used mirrors as a training device, and after a while found they were able to do without them.

Of course, the truck doesn't walk as well as a man. It's stiff-legged and has a rough gait. But since the truck's leg motion is directed by human leg motion, the truck has a smoother gait than would normally be the case with strictly mechanical legs.

A walking truck in your future? If it could go faster and give a smoother ride, it would be a tremendous recreational vehicle. Of course the engineers are working on developing the walking truck to the point where it can move with the agility and liteness of an animal, but that day is a long way off.

But the walking truck shown here already has the ability to outperform wheeled or track-laying vehicles in several respects. It can climb extreme slopes negotiate steep river banks, ford fast-flowing streams—in fact, it would not be much bothered by an obstacle course that would stop a heavy bulldozer dead in its tracks.

As it stands today, military production will not begin until an extensive test program has been undertaken, and the lessons from it have brought about partial redesign and detail improvements wherever possible. Until then, the walking truck is strictly experimental. ■

STOP, DROP, AND ROLL

This autonomous firefighting robot gets its self-preservation instinct from its (very distant) insect cousins

BY MICHAEL DUMIAK

ILLUSTRATION BY JOHN MACNEILL

SHIFTING THROUGH the mossy undergrowth of Germany's Black Forest, antennae raised and leg joints quietly clicking forward, OLE (pronounced "oh-luh") is a St. Bernard-size bug on the prowl. But this mechanized insect isn't a scavenger—it's a guardian.

Only a concept now, OLE (short for "Off-road Loescheinheit," which means "off-road extinguishing apparatus" in German) is a product of the industrial-design studio at the University of Magdeburg-Stendal, about an hour and a half west of Berlin. A robot equipped with tanks of water and powdered fire-extinguishing agents, OLE would be autonomous and guided by GPS, intelligent feelers, and infrared and heat sensors. Design professor Ulrich Wohlgenuth, along with biologist and robot-systems manager Oliver Lange, students, and members of the design firm Transluzent, collaborated on the concept, inspired by the interlinking armor of the common pill bug, *Armadillidium vulgare*.

That armor is OLE's fireproof suit. The six legs have a similar protective purpose. "Walking can be nice, but it is generally useless for robots," Lange points out. "Nature invented walking because it cannot invent the wheel from flesh and blood. In this case, though, if you have wheels, you always have contact with the forest. The concept behind OLE is that he's digging, and he's near heat. Legs don't always have contact with heat." And from a

HARD CASE A segmented shell of heat-resistant ceramic-fiber compounds would protect the guidance system, onboard sensors and power source from harm.

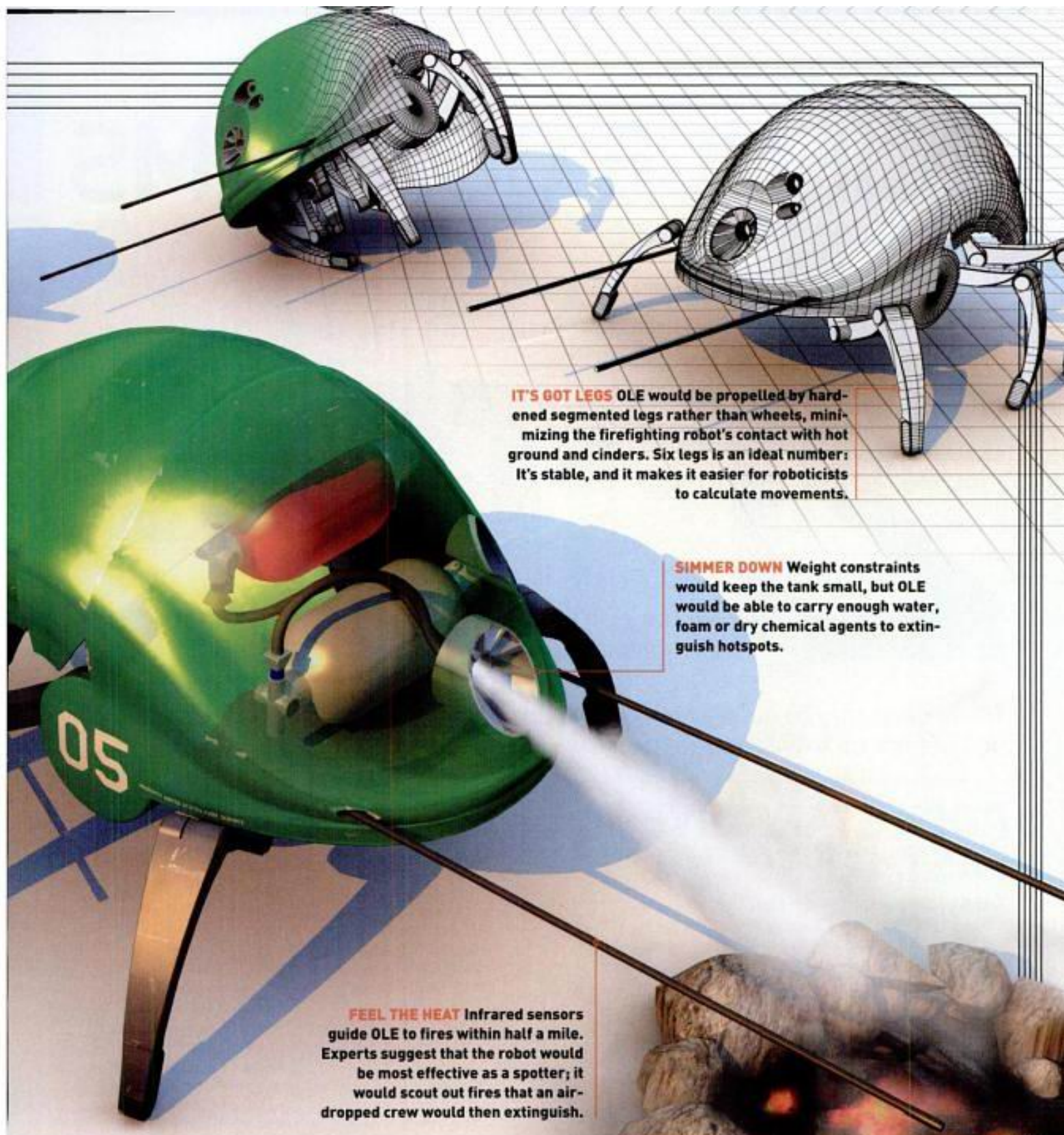


roboticist's perspective, six legs is the perfect number, providing stability and making it easy to calculate movement points.

The designers have suggested two different ways for OLE to do its job. One idea is to place the robots in potential hotspots near towns and campgrounds, where they would remain balled-up, waiting for their sensors to pick up fire within a half-mile radius. Another idea is for the 'bot to patrol

the woods, actively searching for blazes, although battery life and forest obstacles would limit its range.

Wohlgenuth says a working OLE would be made from fire-resistant ceramic-fiber compounds that could withstand temperatures up to 1,850°F. Each one might cost between \$125,000 and \$200,000 and weigh 150 to 200 pounds. And in case pranksters



IT'S GOT LEGS OLE would be propelled by hardened segmented legs rather than wheels, minimizing the firefighting robot's contact with hot ground and cinders. Six legs is an ideal number: It's stable, and it makes it easier for roboticists to calculate movements.

SIMMER DOWN Weight constraints would keep the tank small, but OLE would be able to carry enough water, foam or dry chemical agents to extinguish hotspots.

FEEL THE HEAT Infrared sensors guide OLE to fires within half a mile. Experts suggest that the robot would be most effective as a spotter; it would scout out fires that an air-dropped crew would then extinguish.

wanted to steal one of them from the forest, a GPS beacon on board could be used to track it down.

Forest-fire experts are open to OLE, though many believe that it would be a better scout than firefighter. Margaret Simonson, a fire researcher at the SP Technical Research Institute in Sweden, says the robot would be best used to direct air-dropped firefighting crews. And Henrik

Bygbjerg of the Danish Institute of Fire and Security Technology doubts that it could put out anything other than the smallest fires.

There's no current plan to put OLE into production, but its designers believe that it's more practical than it might sound. Forest fires in Europe burn approximately 1.25 million acres every year. At that rate, an effective force of fire-controlling robots starts to sound attractive at nearly any price.

OLE FIREFIGHTING ROBOT

PURPOSE: Fighting forest fires
DESIGNER: University of Magdeburg-Stendal
DIMENSIONS: 4 ft. long x 2 ft. wide
WEIGHT: 150–200 lbs.
RANGE: One-half mile
TEMPERATURE RATING: 1,850°F
COST: \$125,000–\$200,000

REALLY ALTERNATIVE ENERGY

THE WIND DAM

An architect plans to sling a giant sail over a lake in Russia. Is it the future of wind power—or renewable snake oil?

ONE COMMON COMPLAINT about wind turbines is that they blemish the scenic countryside and coastlines where they perch. Now an architect in London has an attractive solution. The "wind dam," a giant swath of fabric connected to a turbine, looks more like a Christo art installation than a power generator.

The biggest inefficiency of current wind technology, says Laurie Chetwood, founder of the architectural firm Chetwood Associates, is that more wind passes around turbines than through their rotors. So he hit upon the idea of boosting productivity by capturing high-speed winds with a massive spinnaker sail—like those that yachts deploy to pick up extreme speed—anchored to cliffs on either side of a valley and funneling those winds through a central turbine. Based on a computer model of the dam, he expects it to produce up to 120 megawatts per year, enough to power about 35 homes.

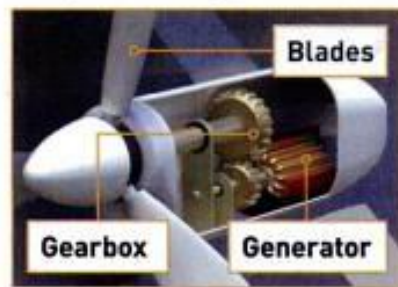
But the design has drawn some criticism. Stephen Connors, a wind-energy

expert at the Massachusetts Institute of Technology Energy Initiative doesn't think the dam could stand up to winds gusting in multiple directions. And, because wind hitting the sail would create turbulence, the dam could struggle to concentrate wind on the turbine. Even if it did, Connors says, the wind would lose significant speed on its way to the rotors.

Chetwood is working on these problems—the sail will probably be conical to limit turbulence, and the architects will build in areas with winds that blow predominantly in one direction to reduce stress on the dam. He has teamed with a Finnish engineering firm and is seeking permission to build a privately financed \$5-million, 17,000-square-foot Kevlar wind dam in a valley close to Lake Ladoga, near the Baltic Sea, as soon as 2009. After that, he may modify the design to fit on a bridge or skyscraper, where at the very least it would give passersby something colorful to look at. Here, a preview of Chetwood's wind dam. —SABA BERRIE

HOW IT WOULD WORK

Two aluminum legs support the 17,000-square-foot Kevlar sail, which is anchored to cliffs in a valley near Lake Ladoga. The conical shape of the sail directs air to three in-line turbines, which are enclosed in a tube. The wind spins each turbine's blades and turns an axle that runs into its gearbox. The gearbox steps up the rotational speed of a shaft that spins magnets around a wire inside the generator to transform the movement into electricity through electromagnetic induction.



TWO MORE ALTERNATIVE WIND TURBINES



Highway Power

A student at Arizona State University has proposed overpass-mounted turbines that, based on windspeeds of at least 10 mph kicked up by cars, could each produce enough electricity to power one small home.



Selsam Superturbine

The floating Superturbine can be moored farther offshore than traditional turbines. Multiple high-speed rotors increase energy output, and a carbon-fiber frame and flexing mechanisms help it survive storms.

contractions in the uterus and stimulating milk production. Researchers have long theorized that it may also play a role in emotional development and bonding.

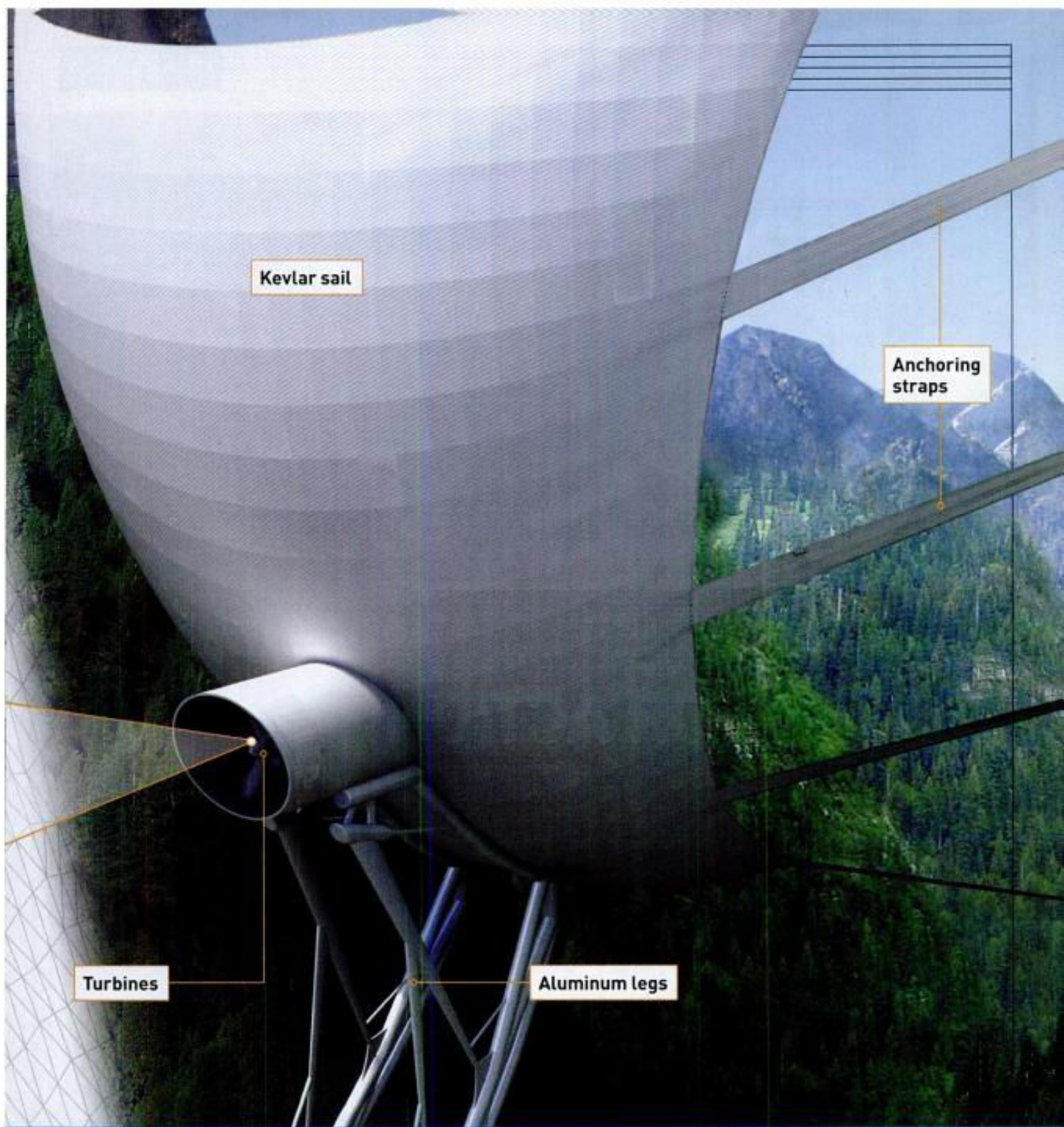
The hormone's ability to enhance social attachment is best documented in mouse-like rodents called voles. In 1994, Emory University scientist Larry Young found that antisocial

montane voles are unable to process oxytocin in brain regions associated with social bonding, unlike their more agreeable cousins, prairie voles. But when Young blocked prairie voles' oxytocin receptors, they became as unfriendly and socially withdrawn as montane voles.

His work has provided the framework for human studies. Gregor Domes, a psychiatrist

at the University of Rostock in Germany led a study in which he gave synthetic oxytocin to healthy men without autism and then showed them pictures of people whose faces were blocked out except for their eyes. Study participants on oxytocin were able to recognize emotion by studying the eyes, performing the task much better than men given a placebo.

ILLUSTRATION: JOHN MACNEILL;
PHOTOGRAPHS: FROM LEFT,
COURTESY JOE DE LEE, COURTESY
MICHAEL SANCHEZ



Kevlar sail

Anchoring straps

Turbines

Aluminum legs

Oxytocin hormone therapy could help the one in 150 kids with autism form tighter social bonds.

Next, Domes plans to determine if the hormone produces a similar effect in autistic patients.

The days of prescription empathy, however, are still several years away. For one thing, researchers need to compile more safety data and test the hormone in children, who would most benefit from

early intervention. For the Mt. Sinai team, the next step is to enroll 20 patients in a six-week trial, with the goal of publishing results in two years. If that study is successful, a much larger one will follow. "Right now," Young says, "we are only seeing the tip-of-the-iceberg effects of oxytocin. It's a very exciting possibility."—MICHAEL ROSENWALD

MILITARY TECH

BEACH CLEANUP

A naval strategy to detonate 70 million mines calls for high-tech showers of darts

SINCE 2001, more than 13,000 American soldiers have been killed or maimed by landmines or improvised explosive devices. Civilians included, landmines kill or injure an estimated 20,000 people around the world every year. To blaze safer trails, the U.S. Office of Naval Research is developing a system that uses thousands of chemical- and explosive-packed darts to snuff out landmines. "It's one of the most successful systems we've tested so far," says project leader Brian Almquist.

Mines are often equipped with a touch or tilt trigger, making them extremely difficult to safely defuse by hand or by robot, and the current method for clearing mines from a safe distance—dropping a large blast warhead on the field—works only on ones laid aboveground. The new system circumvents these problems by employing a cylindrical bombshell packed with 6,500 darts.

When dropped from the safety of an airplane, the GPS-guided bomb

ejects the darts and spreads them out in a 60-foot circular pattern. Each dart is designed to burrow several feet into sand or water, pierce the exterior of a mine, and defuse or detonate it. For safety reasons, any explosive darts that don't hit mines self-sterilize.

Almquist and his team are still modifying the darts, and the project needs approval from the Naval Sea Systems Command Acquisition Program to move out of the lab, but a fieldable system could be ready by 2015.—BJORN CAREY





HOW IT WORKS

1 A plane drops a bomb packed with darts. Once it reaches 1,000 feet above its target, the bomb ejects a seven-foot-long tubular canister.

2 A corkscrew pattern carved into the bomb's interior spins the canister as it slides out, like a bullet leaving a gun. The rotation and small explosives jettison the canister's panels and expose 6,500 darts stacked several rows deep. The mass of darts is also spinning, which uniformly disperses them.

3 Each seven-inch dart slams into the ground at 1,200 feet per second. Its blunt nose helps it carve a channel in water or sand, a process called cavitation. This reduces friction on the body of the dart and allows it to pass through two feet of sand and more than seven feet of water.

4 Darts inject the mines with one of three substances: a chemical that safely burns the TNT, a reactive powder that breaks apart the mine by increasing internal pressure, or a small explosive that detonates the mine on impact.



lone long-term solution to radioactive-waste storage, will stow just 77,000 tons when it's slated to open in 2020.

Yet not everyone thinks GNEP's strategy for recycling waste is the solution. Ivan Oelrich of the Federation of American Scientists, for example, says that the new type of recycled fuel would contain as much as 90 percent plutonium, making it a much more attractive target to a bomb-building terrorist. Spent fuel from traditional reactors, by comparison, contains only 1 percent plutonium.

GNEP officials reject this criticism. The new recycling process, they argue,

New reactors could produce 40 percent less waste than conventional ones.

will not isolate pure plutonium, making it more difficult to convert the leftovers into a bomb. Specifically, the process calls for dissolving spent fuel in nitric acid to chemically extract the nastiest 1 percent—the highly radioactive elements plutonium, neptunium, americium and curium, also known as actinides—as well as depleted uranium. (The remaining waste is stored in traditional casks.) The uranium is then re-enriched, recombined with the actinides, and compressed into fuel pellets for state-of-the-art reactors. In this scheme, waste is used repeatedly, transforming it into less harmful elements with each cycle.

The Oak Ridge demonstration is intended to be a miniature model (minus the reactors) of how this recycling process could work at the industrial scale. "It's a synthesis of the whole process," says Greene, who is working on the project.

In addition to pursuing scaled-down tests of the new recycling technology, GNEP officials will release a draft report this summer on the environmental impact of the potential sites. But the program's defining moment will happen next year when the U.S. secretary of energy decides whether to step up the initiative and build America's first full-scale demonstration plant.—SETH FLETCHER



CATEGORY: SPORT PERFORMANCE
BREAKTHROUGH TECH: ELECTRIC HUB MOTORS
FOUR-SEAT AERODYNAMIC POD

JAVELIN SPEEDSLED

SUPERCAR SEATS FOUR

No longer must drivers confine themselves to the limitations of conventional sports cars, with cramped interiors, aerodynamically compromised styling and body-battering ground clearances. The new all-electric sport cruiser's performance-tuned suspension cuts aggressively through turns, while its four powerful hub motors—individual electric motors built into the wheels that generate a combined 450 horsepower—send it blasting down straights, reaching 60 mph in less than four seconds on its way to a top speed of 200 mph. But the real innovation is its aerodynamics: Instead of fighting high-speed airflow, the car takes advantage of it, channeling the air around the central, low-slung pod to generate huge downforce. Furthermore, the hub motors eliminate the need for a large engine, freeing space for three passengers to ride in a unique 1+2+1 seating configuration.

EXOSKELETON

Exposed structural components are shaped to reduce drag and direct airflow around the central passenger pod.

HIGH RIDE

The clean underbody and high-downforce aerodynamic pod permit higher ground clearance than conventional supercars. This generates a more comfortable ride without hindering high-speed performance.

WHEEL FAIRINGS

Streamlined pods minimize the tendency of exposed wheels to create lift.

SMART SEATING

Passenger pod minimizes drag with a tapered front and rear shape. Inside, you'll find an unusual 1+2+1 tandem-seating configuration.

WHEEL POWER

Four lightweight 85-kilowatt electric hub motors eliminate the need for a large engine. They also integrate shock absorbers, brakes and drive-by-wire steering controls into the wheels.

AERODYNAMIC MORPHING

Based on your preferences, front- and rear-wing surfaces morph to an ideal aerodynamic shape to either increase downforce or reduce drag, thereby improving efficiency.

VARIABLE COLOR

Electrochromic paint can be adjusted to any hue, with natural fades between colors. Program your car to cycle through color schemes as you accelerate.

FRONT POWER

A 150-kilowatt (200hp) electric motor drives the front wheels.

INTEGRAL HUD

A head-up display embedded in the windshield provides navigational data and highlights obstacles.



COMPACT UTILITY

The retracted configuration permits tight maneuvering.



CREW CAB

The cab seats five, with an easily accessible rear bench.

TRUNK ON DEMAND

A tonneau cover deploys automatically when the pickup bed retracts.

REAR POWER

Another 150-kilowatt (200hp) electric motor drives the rear wheels, eliminating the need for a central driveshaft.

CATEGORY: **ADAPTIVE UTILITY**

BREAKTHROUGH TECH: **EXTENDABLE PAYLOAD BED, HIGH-POWER DRIVE MOTORS**

EXTENDER

E L A S T I C T R U C K

STRETCHING POSSIBILITIES

This truck fits your life. It's efficient, clean, tough as they come—and has one big trick up its sleeve. The Extender, a 400-horsepower, all-electric, four-wheel-drive monster (which uses the most powerful DC motors yet devised for the automotive industry), has an adjustable payload bed. When not in use, the bed retracts unobtrusively into the rear of the truck. It extends by way of an electric piston up to a full-size 4x8 bed with thin-but-sturdy armored sidewalls and a structural support system that can handle the toughest terrain and the heaviest loads.



FLY THE FRIEND



▲ **WAVE JUMPING** Rough waters are no problem for a boat that sails above the waves.



▶ **A SPRING IN ITS STEP** The Sea Phantom's outriggers extend at 35 mph and can be adjusted to enhance maneuverability.

▼ **SEA SPOT FLY** The 34-foot Sea Phantom prototype gets a workout off the shores of Fort Myers Beach, Florida.

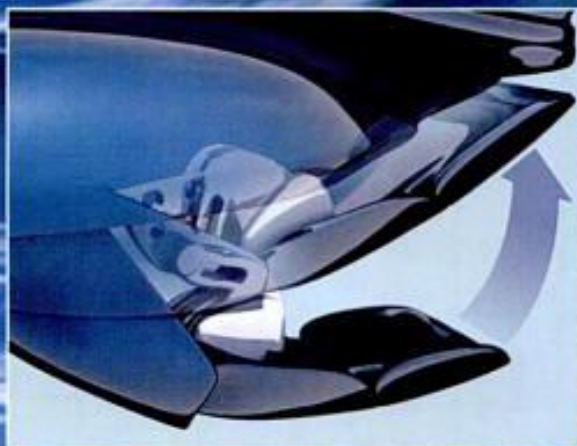


ILLUSTRATION: PETER BOLLINGER; PHOTOGRAPH: JOHN B. CANNETT

LY SEAS

The unholy offspring of a speedboat and an experimental aircraft is a welcome mix of velocity and economy



SEA PHANTOM

PURPOSE: A highly efficient watercraft that can move fast and negotiate heavy seas

MANUFACTURER: Maritime Flight Dynamics, Inc.

DIMENSIONS [feet]: 34 (length); 12.6 (wingspan)

ENGINE: 550-horsepower inboard V-10

TOP SPEED: 120 mph

CAPACITY: Five passengers

COST: \$500,000

AS THE SEA PHANTOM races along at 120 miles an hour, passengers sitting comfortably eight feet above the water might forget they're in a boat and not a low-flying jet. That's the idea, says inventor David Borman, who has crossbred a powerboat with an experimental airplane to create the most unconventional watercraft since the hydroplane. Larger versions of his 34-foot prototype, Borman says, could someday provide an alternative to regional flights and lumbering ferries, whisking passengers between coastal cities.

At rest, the Phantom looks like a half-submerged UFO. Once it hits 35 mph, though, a transformation begins. Six-foot-long curved foils drop down from the wings, and the boat rises up on them like a water-skier. Air flowing under the body lifts the craft out of the water's drag. This makes the Phantom highly efficient—water is roughly 800 times as dense as air—so the boat requires only one fifth the amount of gas used by a conventional craft of the same size.

Aircraft influences don't stop at the shape, either. The Phantom banks into turns like an airplane, retracting its inside foil and extending the outer one to carve at high speeds. "It'll pretty much outmaneuver anything on the water," Borman boasts.

The son of two pilots, Borman was inspired by 1960s NASA aircraft that generated lift from the shapes of their bodies instead of wings. His boat capitalizes on the same principle. At 100 miles an hour, air supports up to 85 percent of the boat's weight. Only a small section of each foil, along with the propeller in the tail, even touches the deep blue. In addition to allowing for effortless speed, this cushion insulates the Phantom from heavy seas. The boat can negotiate up to eight-foot swells without slowing down.

These performance capabilities have attracted the interest of more than a few suitors, including U.S. Naval officials who envision it transporting SEAL teams. Borman sees it as a coastal ferry or a Caribbean island hopper. But he's also betting that a few deep-pocketed private boaters will plunk down \$500,000 to fly the fastest, wildest boat to hit the water in years.

—GREGORY MONE

THE TRUTH ABOUT NANOPOLLUTION

Nanotech is here. It's in your clothes, your food and your home.

But can it hurt you? BY JR MINKEL ILLUSTRATION BY MEDI-MATION

THE WORRY

Nanoparticles—defined as particles less than 100 nanometers across—are used to improve the efficiency and durability of more than 200 different consumer products already on the market, including sunscreen, stain-resistant trousers and golf balls. But their potential health and environmental effects are largely unknown.

THE WATCHDOGS

European officials have established dedicated research groups such as Nanosafe 2 and Impart-Nanotox to figure out how to detect, track, and evaluate nanoparticles. Research in the U.S. is less coordinated, but groups of scientists at Rice University and the University of Rochester have similar goals.

THE THEORIES

It's thought that nanoparticles, being so small, can easily enter cells and could damage living tissues (larger particles remain trapped outside of cells). Studies suggest that they may be able to diffuse into the rest of the body if inhaled, swallowed, or absorbed through the skin. Once exposed to living tissues, chemically reactive particles could tear up DNA, RNA or important enzymes or disrupt other cellular machinery, causing acute sickness or long-term health problems. In a 2004 study, for example, a Duke University researcher found that a specific kind of carbon—a buckminsterfullerene, or "buckyball"—dissolved in water caused significant damage to brain cells in freshwater fish.

SNEAK ATTACK

How nanoparticles could infiltrate the brain.

1 In studies done on rats (whose neurons are similar to those of humans), the animals inhale ultrafine particles—say, carbon nanotubes—which lodge in the nasal cavity.

2 The particles diffuse, working into and between cells, until they reach the olfactory nerve just behind the throat.

3 Finally, they travel along the olfactory nerve into the brain, where they damage cells and impair brain function.

Damaged area

FAQs Zooming in on the tiniest of health threats

WHAT ARE NANOPARTICLES GOOD FOR, ANYWAY?

There are countless uses. Zinc oxide nanoparticles are perfect for sunscreens because they block ultraviolet rays but appear transparent. Semiconductor nanoparticles are efficient light emitters, and fullerenes are used as lubricants.

HOW DO WE KNOW IF THEY ARE SAFE?

Currently, researchers introduce commonly used nanoparticles into test organisms (rats, fish, plants and microbes) and look for them to collect in the organs, where they may damage tissue. Researchers believe, however, that a multi-tiered approach—tests on cell

cultures combined with animal studies—will be necessary to truly get a handle on the potential human toxicity of a given nanoparticle.

CAN THEY BE MADE SAFER?

Nanoparticles can be coated with other substances to make them potentially less

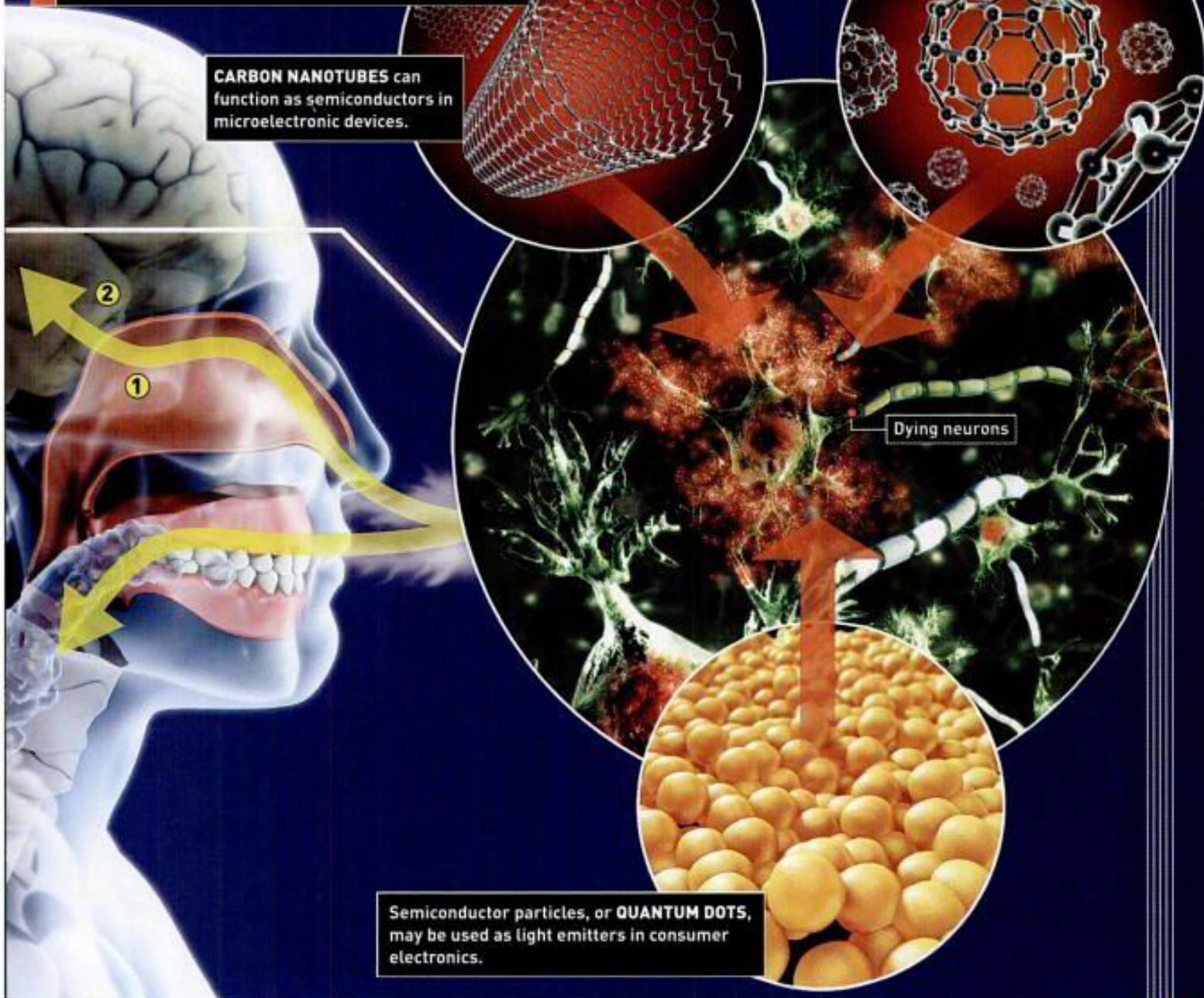
reactive, but such coatings might nullify their useful properties. Containment is key. Certain clays used to line landfills seem to be able to prevent buckyballs from escaping into the environment, according to Joseph Hughes, professor of civil and environmental engineering at the Georgia Institute of Technology.

LITTLE RASCALS

Common nanoparticles researchers will keep an eye on.

CARBON NANOTUBES can function as semiconductors in microelectronic devices.

BUCKMINSTER FULLERENES: Coatings and solid lubricants use this form of carbon.



Semiconductor particles, or **QUANTUM DOTS**, may be used as light emitters in consumer electronics.

TIMELINE

1985

American and British researchers discover the buckminsterfullerene. "Buckyballs" are another form of carbon, along with graphite and diamond.

1991

A Japanese scientist discovers the carbon nanotube, which comes in single-walled and multiwalled varieties. Single-walled nanotubes have unique electronic properties.

2000

The Jumbotron lamp, which has lit places such as sports stadiums for decades, incorporates nanotubes as light emitters and is introduced for sale commercially.

2005

Buckyballs are found to curtail microorganism growth and to damage neurons in lab tests. It's unclear if they would be harmful after traveling through the body.

2005

Alumina nanoparticles stunt the growth of plant roots in the lab. The levels needed are so high, however, that real plants would have to be swimming in the stuff.

2006

Six Germans are hospitalized with lung problems after using an aerosol sealant called Magic Nano. It is unknown whether the product's nanoparticles were to blame.

FUTURE TECH: MILITARY

SEMPER FLY

A proposed Marine Corps suborbital space transport will put boots on the ground anywhere in the world in two hours or less. But can it overcome huge technological—and political—hurdles?

BY DAVID AXE

ILLUSTRATIONS BY
PETER BOLLINGER



HOSTAGE RESCUE Minutes after receiving their orders, armed Marines board their spaceship at a secret base in North America. The craft will be carried aloft by a mothership and launched into space from 80,000 feet. Less than two hours after leaving the base, the Marines will land in hostile territory in Southeast Asia.



THREE KEY FACTS

- 1** The Marine Corps sees suborbital transport as a way of almost **instantly putting its troops** anywhere on the globe.
- 2** The technologies for a **Marine space vehicle** are in development, though in programs spread across the military.
- 3** The vehicle will need **advanced scramjet and rocket propulsion** and must be able to withstand rough landings.

As any battlefield commander will tell you, getting troops to the fight can be as difficult as winning it. And for modern-day soldiers, the sites of conflict are so far-flung, and the political considerations of even flying over another country so complicated, that rapid entry has become nearly impossible. If a group of Marine Corps visionaries have their way, however, 30 years from now, Marines could touch down anywhere on the globe in less than two hours, without needing to negotiate passage through foreign airspace. The breathtaking efficiency of such a delivery system could change forever the way the U.S. does battle.

The proposal, part of the Corps's push toward greater speed and flexibility, is called Small Unit Space Transport and Insertion, or Sustain. Using a suborbital transport—that is, a vehicle that flies into space to achieve high travel speeds but doesn't actually enter orbit—the Corps will be able, in effect, to instantaneously deliver Marine squads anywhere on Earth. The effort is led by Roosevelt Lafontant, a former Marine lieutenant colonel now employed by the Schafer Corporation, a military-technology consulting firm working with the Marines. Insertion from space, Lafontant explains, makes it possible for the Marines—typically the first military branch called on for emergency missions—to avoid all the usual complications that can delay or end key missions. No waiting for permission from an allied nation, no dangerous rendezvous in the desert, no slow helicopter flights over mountainous terrain. Instead, Marines could someday have an unmatched element of surprise, allowing them to do everything from reinforce Special Forces to rescue hostages thousands of miles away.

"Sustain is simply an ability to move Marines very rapidly from one place to another," says Marine colonel Jack Wassink, director of the Corps's Space Integration Branch in Arlington, Virginia, where the program is based. "Space lends itself to that role."

The program is quickly gaining traction. Congress has expressed interest, because of the obvious usefulness of the capability it promises. And the technologies necessary to make it happen, from hypersonic propulsion

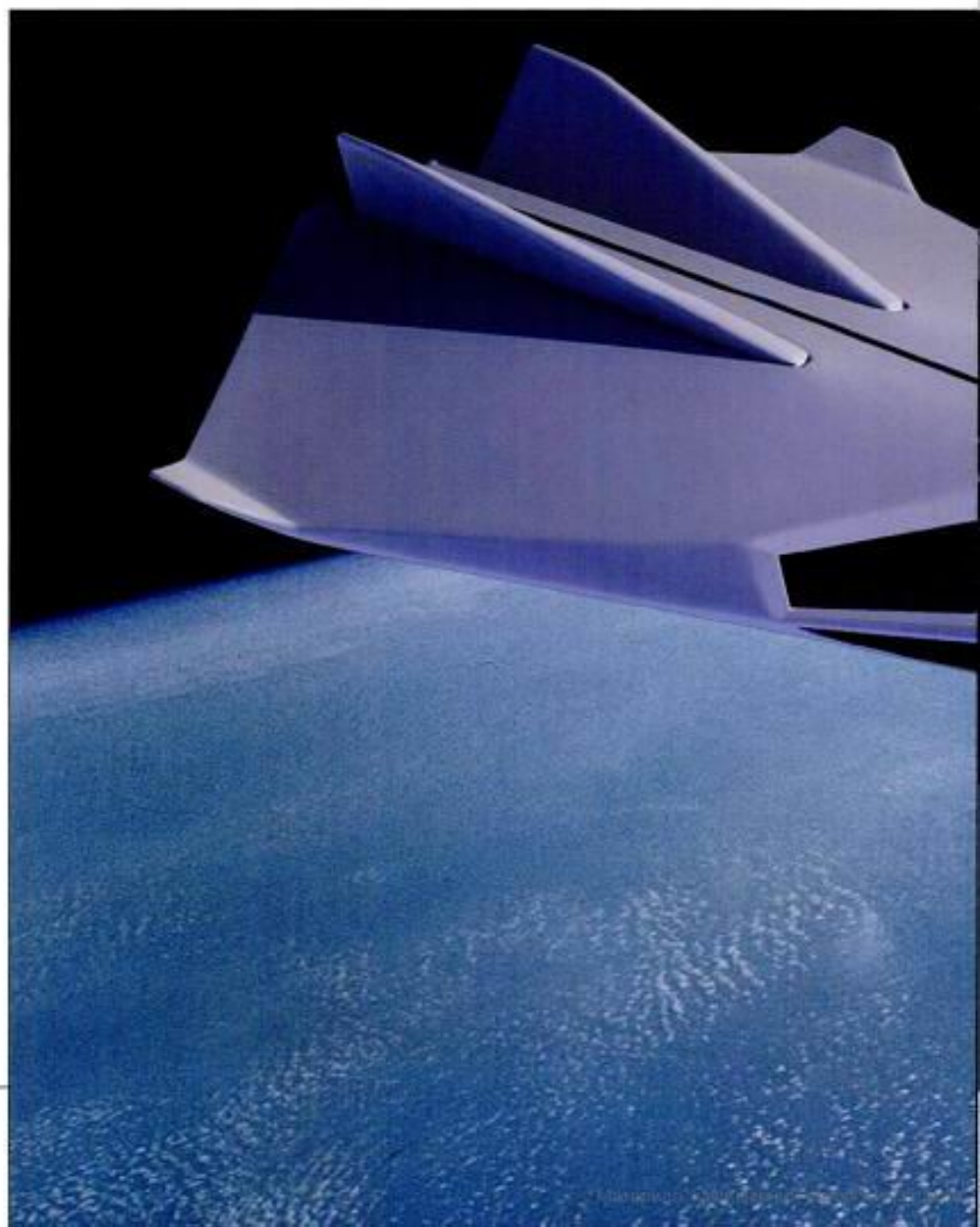
systems to new composite materials needed to make the vehicle lightweight yet strong, are in advanced development in military labs across the country. The Marines expect to fly a prototype in 15 years, most likely a two-stage system using a carrier aircraft that will

launch a lander into orbit from high altitude. Production models could show up around 2030, a date that isn't quite as far away as it seems. Consider that the F-22 Raptor fighter is now entering service after 22 years of development.

But the whole idea still rings of science fiction, and the question is whether its proponents can corral the various technologies together to make the project possible. "Sustain is not a pipe dream," Lafontant says. "It just needs to gel."

OVERSTEPPING BOUNDARIES

Finding routes through diplomatically friendly airspace and then arranging for timely delivery of U.S. forces are key complications, especially on today's world political stage. Sustain would solve both problems in a single stroke.



According to international agreement, a nation's airspace extends 50 miles from the Earth's surface, just short of low orbit. A spacecraft would allow the U.S. to step over other countries and insert forces where they're needed.

Each Sustain lander is intended to hold a squad of 13 Marines. Mounted on wedge-shaped carrier aircraft, the lander would detach, climb, and accelerate with scramjet engines to 100,000 feet and then fire rocket engines to get above 50 miles, following an arc over hostile countries. Composite shields would absorb or deflect the searing heat of reentry as the vehicles angle for the landing zone.

Lafontant arrived at this Space Marines vision after years of analyzing military space needs. A 44-year-old Queens, New York, native who joined the Corps in 1984 as an infantry offi-

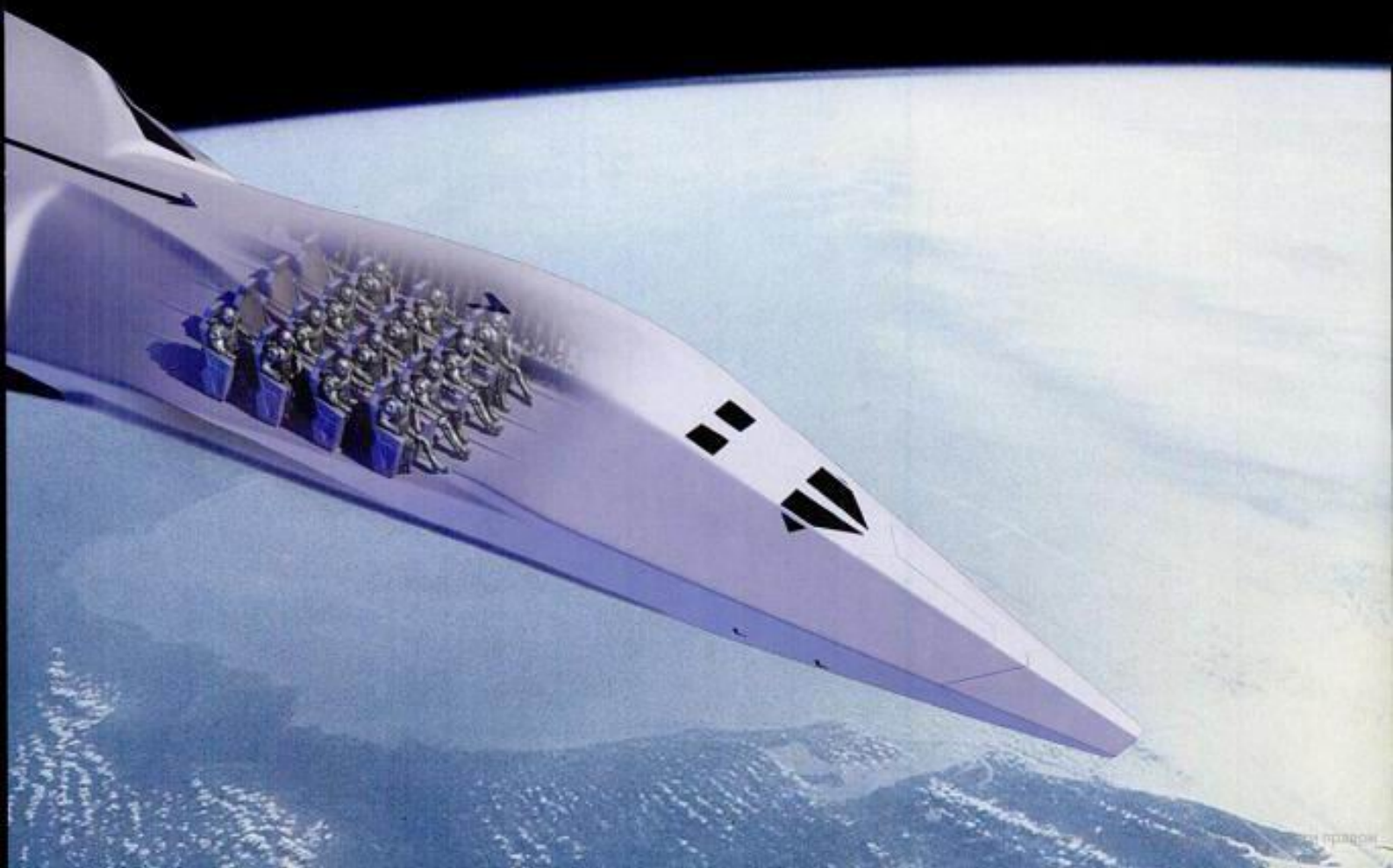
cer and progressed through Naval Postgraduate School in Monterey, California, where he studied space systems operations and joined the small fraternity of Marine Space Operations Officers. In 2001 he took a job in the Pentagon working for the National Reconnaissance Office. He was serving as liaison to the Joint Chiefs of Staff in November 2001 when the Marine Corps launched its deepest air assault ever.

Five hundred Marines from the 15th Marine Expeditionary Unit prepared to fly 441 miles through the mountains of northern Pakistan in CH-53E Sea Stallion helicopters to capture an airstrip near Kandahar, Afghanistan. It was to be the beginning of the first large offensive against the Taliban and Al Qaeda. If all went well, the Marines expected to walk away with Osama bin Laden.

But political considerations sabotaged the mission. For weeks, the Marines had bobbed on the Indian Ocean aboard two assault ships while State Department officials negotiated with Pakistan for the right to fly through the country's airspace. Pakistan granted access only after winning economic and military concessions that, some say, have reinforced a repressive regime. When U.S. troops finally touched down on November 25, bin Laden's trail was cold. "We ended up selling our soul to the devil to get through," Lafontant says. He grew determined to find a way around that sort of diplomatic entanglement. "What if we don't have to have anybody's permission?" he asked himself. "What if we just go above and drop in?"

In April of that year, while Marines

MOD SQUAD The lander, with the squad of 13 Marines and two pilots on board, will travel the 7,000 miles to Southeast Asia in mere minutes by flying above the atmosphere.



were bogged down in bloody cave fighting during the hunt for bin Laden, Lafontant had lunch with fellow space expert Franz Gayl in the Pentagon cafeteria. Gayl, also a former Marine with significant influence in the private sector, brainstorms new technologies for the Corps's Plans, Policies, and Operations Department. Lafontant suggested that a space transport could have allowed Marines to nab bin Laden without a major assault—and before the terrorist leader could disappear into Afghanistan's caves. Gayl was skeptical of its feasibility—the idea of military space transport has been around for decades yet has never been deemed viable enough to enter active development—but he was impressed by the elegance of the solution and its use of military technology that he knew to be in the works.

Together, Lafontant and Gayl formally presented their concept to Gayl's boss at the Pentagon, brigadier general Richard Zilmer, and then to lieutenant

general Emil Bedard, the office's deputy commandant, who endorsed it on July 22, 2002, adding space transport to the Marines' official wish list. But the technology—reusable and advanced propulsion, sophisticated heat shielding—wasn't ready. Just a year earlier, two joint NASA and Air Force programs to develop similar reusable launch vehicles, or RLVs, had been canceled because of problems with their single-stage engines. The idea was far ahead of the technological curve.

But Lafontant was patient. He continued to refine and promote the space-transport idea until it was a fixture in the collective imagination of the Marines' space community. Soon Sustain found a home at the Corps's Space Integration Branch in Virginia, where Wassink directs a 100-person team of satellite technicians who connect Marine commanders to operations around the world. Wassink was interested in the Sustain project, but the Marine Corps is a small force under

the umbrella of the Navy and receives just 4 percent of military funding. Sustain is "certainly not something the Marine Corps would be able to acquire on its own," he admits.

Zilmer agreed and introduced the Sustain concept to Congress. In an address to a Senate committee in July 2003, he outlined the Marine strategy. "We must coordinate and synthesize our technology needs with other Department of Defense and nonmilitary users," Zilmer told the committee. He mentioned NASA as a possible partner. Lafontant also foresaw the Air Force developing the carrier aircraft and the Defense Advanced Research Projects Agency (Darpa), the Pentagon's experimental-science arm, overseeing the design of the lander. Zilmer's testimony was part of a broad campaign that Lafontant and the other Sustain advocates launched to sell the idea to Congress, NASA, the Air Force and Darpa, and to the industry partners that would build the

THE EXPRESS ROUTE

A future long-range lander will launch into suborbital space from a carrier craft [1]. The lander will fire its own rockets for the ascent into space and then coast to the conflict area [2], where it will reenter the atmosphere and fly to a touchdown [3].



INSERTION POINT
After their brief high-speed flight and landing on a roadway, the Marines disembark in a hostile city, ready for action.



hardware. "We saw the entire gamut of reactions," Wassink recalls. "Some people didn't get past the giggle factor."

MARINES INTO SPACE

The Marines have a history of selling risky but revolutionary concepts. They embraced amphibious assault before it became a deciding factor in World War II. They guarded the versatile V-22 Osprey tilt-rotor plane during its troubled development. And they have championed their share of flops. Their vertical-takeoff AV-8B Harrier crashes more than any other contemporary fighter, and it was the Marine Corps, after all, that seriously investigated attaching incendiary bombs to thousands of bats during World War II.

Sustain is part of the latest in a long legacy of tough sells. But, as the world stage grows more hostile and the need for rapid, flexible deployment grows more intense, Lafontant insists that "the giggle factor is gone now."

The Sustain program is not only risky, it also requires the cooperation of researchers from multiple branches of the armed forces that are currently developing relevant technologies. The Sustain system will consist of two stages: a launch craft and a lander. In recent years, NASA, the Air Force and the Navy have created programs to develop new RLVs that will use multi-stage systems and a combination of rockets and hypersonic air-breathing

A MARINE SPACE TRANSPORT MIGHT SOUND IMPOSSIBLE, BUT TO SOME, IT IS SIMPLY THE NEXT LOGICAL STEP.

boost engines. Vehicles now in development that could be adapted for a Marine carrier aircraft—the first-stage launcher that will carry the actual spaceship—include the hypersonic aircraft Falcon, which skirts the upper atmosphere; the Boeing X-51 and Lockheed Martin Rattlers (Revolutionary Approach to Time-Critical Long-Range Strike) hypersonic engine testbeds; and the supersecret two-stage spacecraft Hot Eagle. It's this constellation of programs, along with aviation designer Burt Rutan's two-stage spaceplanes, that will ultimately yield Sustain's RLV transport.

Falcon, a \$100-million Air Force program intended for low-orbital operations from a runway, is the centerpiece. The first two Falcon vehicles—long, wedge-shaped craft—are under construction by a Lockheed Martin team in Palmdale, California, and are slated to begin testing in 2008.

ROUGH LANDING

At the core of Sustain is the lander—the actual vehicle in which a squad of 13 Marines [see illustration, facing page] and their gear will float through space,

reenter the atmosphere, and come down right on top of their adversaries. The closest thing to a Sustain lander actually flying today is Rutan's *SpaceShipOne*, built by Scaled Composites in Mojave, California. In October 2004, *SpaceShipOne* piggybacked to 40,000 feet on a carrier aircraft and then boosted to 69 miles with its own rocket and landed like an airplane. This singular feat, perhaps more than any other accomplishment by industry or researchers, has energized proponents of Sustain. "Just a scaled-up version of that would do this [Sustain] mission," said then-Air Force general S. Pete Worden while observing the launch. A lander based on *SpaceShipOne* would be bigger, tougher and armed—and reconfigured for longer flights, as opposed to the up-and-down trajectory that *SpaceShipOne* flies—but the basic concept is broadly the same.

Worden, who had heard one of Lafontant's early Sustain pitches, is now director of the NASA Ames Research Center in California, where he is one of Sustain's biggest allies. It was the

(CONTINUED ON PAGE 89)

POPULAR SCIENCE

GADGET
OF THE MONTH

YEEEEEEHAW

THE
FUTURE
NOW

The Sled That
Goes 60 mph P.26

MARINES IN SPACE

An Audacious Plan to Get
Our Troops **Anywhere**
in 2 Hours or Less P.56



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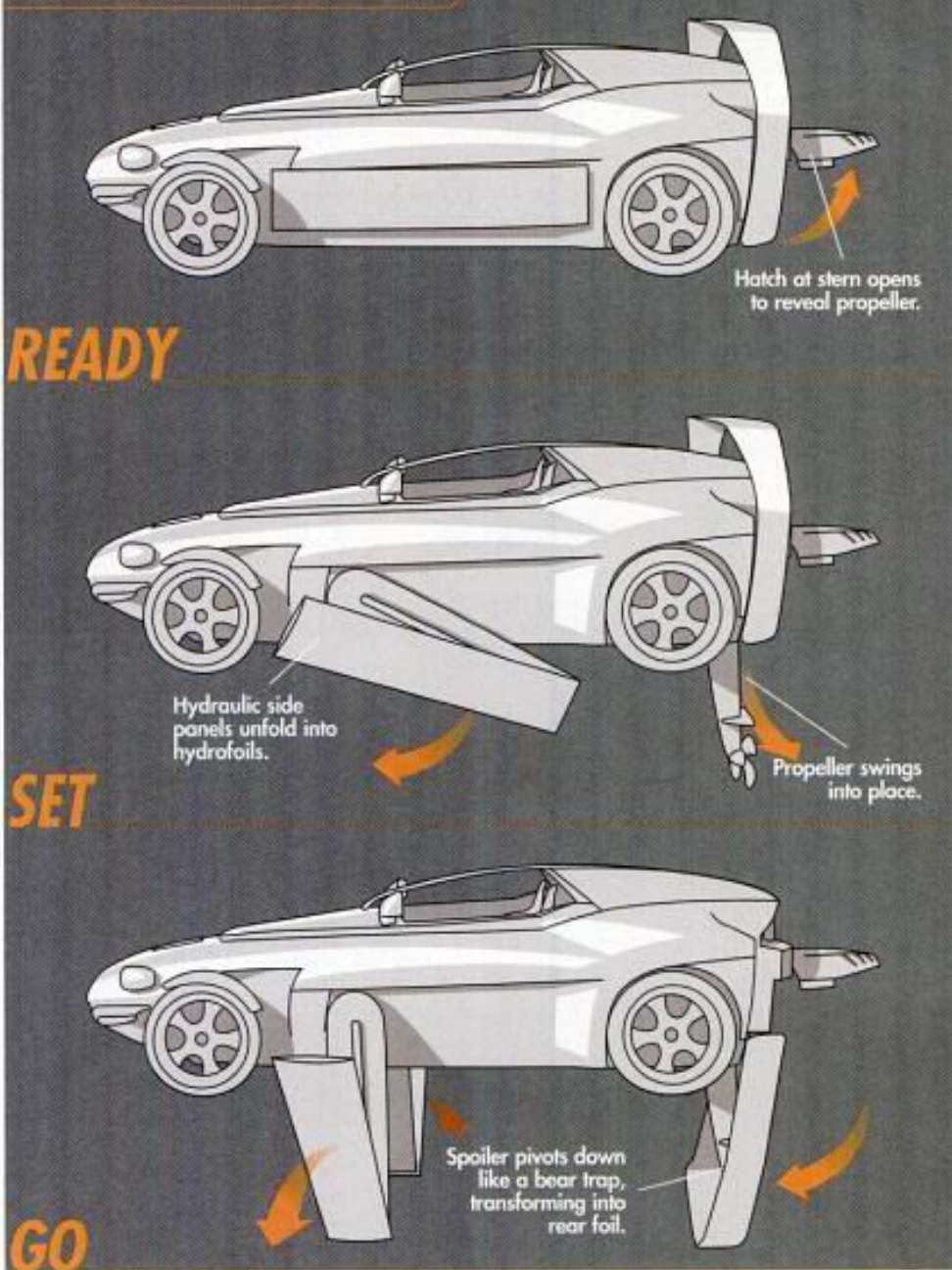
What's New

THE ULTIMATE CONVERTIBLE

A ZIPPY LITTLE CAR-BOAT-HYDROPLANE FROM SOME SERIOUS PROPELLERHEADS.

Long known as the go-to guys for souping up Porsches with delightfully absurd levels of power, the auto tweekers at Switzerland-based Rinspeed have taken the next level to the next level with their latest concept car, the Splash. Although there are plenty of car-cum-boat combos out there [see the Gibbs Aquada in "Best of What's New," Dec. '03], the Splash is the first that transforms into a hydroplane. (It debuted at the Geneva auto show in March.) Powered by a 140-hp turbocharged two-cylinder engine that runs on either methane or petroleum-based gas, the Splash can hit 30 mph as a boat or 50 mph as a hydroplane (that's fast), and as a car it'll dart from 0-to-62 mph in 5.9 seconds. At sea, a rear propeller swings down from beneath the watertight engine compartment to drive the Splash. The same propeller steers it, with a little help from the front wheels when you're using it as a boat. The lightweight, carbon-composite body is equipped with buoyancy chambers and bilge pumps, should a rogue wave crash over the open cockpit. The only real downside is that you're advised to sport a life preserver on land as well—the transformer has no airbag, if you can believe it. —JOE BROWN

THE HYDROPLANE TRANSFORMATION

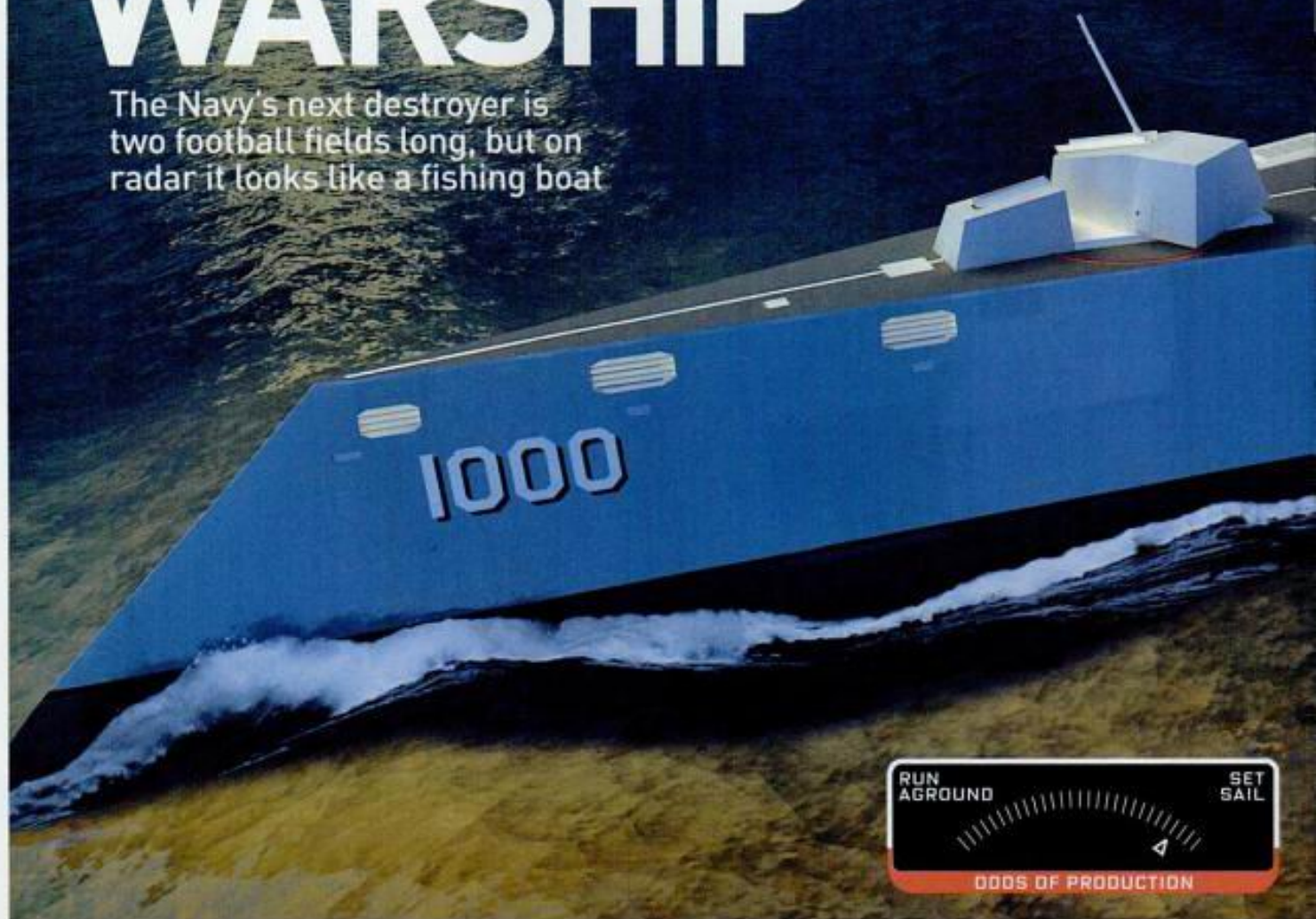


CONCEPTS & PROTOTYPES

INNOVATION BEGINS HERE

INVISIBLE WARSHIP

The Navy's next destroyer is two football fields long, but on radar it looks like a fishing boat



IT WILL BE ALMOST silent, nearly invisible to enemy radar—and capable of dropping six powerful missiles simultaneously on a single target up to 95 miles away. But the most important feature of the DDG1000 Zumwalt, the Navy's first new destroyer in 30 years, could be its versatility. The 600-foot-long ship will be just as comfortable in the deep ocean as in the mine-infested shallows of the Persian Gulf.

Yesterday's big boats were designed for open-water standoffs, not hostile coastlines. They show up like

giant bull's-eyes on land-based radar installations. And the ships lack sufficient sensor systems to dodge the waterborne mines common to enemy harbors.

That's not going to cut it for the fleet of the future. Captain Jim Syring, the DDG1000's program manager, says the need for littoral dominance is obvious if you consider the shallow waters near potential conflict regions: "All you've got to do is look at the areas of interest: the Persian Gulf, the Sea of Japan, the Korean Peninsula."

Whether it's dropping off a SEAL team or launching missiles inland, the Zumwalt is going to have to slip in unnoticed. It will be quiet—the diesel engine's noise will be stifled by an inch-thick rubber coating that Syring likens to elephant skin—and stealthy. The spinning dishes and antennas common to today's ships easily register on enemy radar, so the DDG1000 will instead feature communications hardware that lies flat, embedded in the skin of the deckhouse. This sleek design, combined with a hull that



HIDDEN POWERS

The two massive guns fold down and tuck away for stealth.



BIG EARS The front part of the bow contains a formidable sonar array for sniffing out mines and enemy subs.



ATTACK PATIO The stern deck of the ship is a landing pad for helicopters, unmanned aerial vehicles and other aircraft.



slopes inward from sea level up, rather than outward like most ships, will scatter the energy from an enemy's radar. According to Syring, on scanners the Zumwalt will look like a fishing boat.

Though hard to find, the DDG1000 will announce its presence with a bang. The Advanced Gun System will be able to fire 600 GPS-guided Long Range Land Attack Projectiles in only 30 minutes—or plant six of them in the same spot at the same time. Staggered around the ship's perimeter, 80 launchers packed with Tomahawks and other

missiles will provide additional power.

For added protection, a new dual-band radar system that searches both the sky and the sea surface will be able to locate something as small as a terrorist speeding in on a Jet Ski, and the ship's bulbous front protrusion sports a super-sensitive sonar array for identifying underwater minefields. All that's left now is to start cutting metal. Construction on the first of seven ships is expected to start early next year, with a planned delivery date of 2012.

—GREGORY MONE

DDG1000 ZUMWALT

PURPOSE: Multi-mission destroyer designed for shallow-water dominance

MANUFACTURER: Northrop Grumman and General Dynamics

DIMENSIONS [feet]: 600 (length); 80.7 (beam); 27.6 (draft)

WEAPONS: Two 155-millimeter Advanced Gun System launchers; 80 Advanced Vertical Launch System cells; two 57-millimeter close-range guns

COST: \$2.3 billion

CONCEPTS & PROTOTYPES
INNOVATION BEGINS HERE

WARSHIPS OF TOMORROW

BY CHRISTIAN DeBENEDETTI
ILLUSTRATION BY NICK KALOTERAKIS

Sleek designs, robotic aircraft
and next-generation weapons
will make the ships of the future
the most formidable ever



PROPOSITION: Will the
U.S. Navy order its first CG(X)
missile cruiser by 2011?

PPX BET ON THE FUTURE
AT PPX.POPSCI.COM



THE UXV COMBATANT

PURPOSE: A stealthy base at sea for unmanned planes, tanks and subs

MANUFACTURER: BAE Systems

SPEED: 31 knots

DIMENSIONS (ESTIMATED): 500 ft. (length), 70 ft. (width)

CAPACITY: 60+ crew members, and a minimum of 24 combat drones

COST: Not yet announced

LAUNCH DATE: 2020 at the earliest

STATUS: Very much a concept—plans were only recently unveiled—but hull design is based on an existing ship.

JUNKYARD

SHIPYARD

ODDS OF PRODUCTION

It's hard to tell what kind of wars the future will bring, but one thing is certain: Robots will be doing much of the fighting. In fact, they already are. Last year, aerial drones flew 258,502 hours of missions—up from 27,201 in 2002. Spending on unmanned aircraft systems by the U.S. military is expected to hit \$3.76 billion by 2010. Robotic warfare, long the stuff of science fiction, is now a reality.

That's why, late last year, the British defense company BAE Systems released plans for a fast-moving, specially built home at sea for these robot warriors. That ship is the UXV Combatant concept: part warship and part next-gen carrier for unmanned craft.

From a ship-design standpoint, the best thing about unmanned vehicles is that they can be launched from small spaces that a manned craft simply can't. "It's a violent thing to launch an aircraft off a carrier—you can only stress the human being so much," says Charles Thompson of BAE Systems. Take the human out of the equation, and you can launch a vehicle from a much smaller space—which saves room and allows the UXV to function both as a fast, stealthy warship and an aircraft carrier at the same time. On the UXV, two 164-foot decks joined in a V shape would slingshot unmanned vehicles into the air

(CONTINUED ON PAGE 42)

MEET THE NAVY OF THE FUTURE

TWO YEARS AGO, the U.S. Navy embarked on an ambitious 30-year plan to transform its fleet from the current level of approximately 280 ships—the smallest since 1916—into a versatile 313-ship force. The three advanced ship designs you see here would be the Navy's main surface-based fighting machines. (Eleven aircraft carriers, 66 submarines, 31 amphibious ships, 42 big supply ships, and various support ships would fill out the fleet.) The plan should prepare the Navy to fight both large-scale battles against well-equipped enemies and skirmishes with terrorists and other small, nimble adversaries. But cost overruns and questions about key technologies have already caused setbacks. Will the Navy reinvent itself by its deadline? We checked in on its progress.—MICHAEL BELFIORE

THE LITTORAL COMBAT SHIP (LCS)

PURPOSE: This is a small, fast ship (capable of 45 knots) for sub-hunting, mine-clearing, and fighting small boats near coastlines—the littoral region. Each LCS would be equipped with one of three distinct mission modules: a set of plug-and-play ship sensors, missiles, small boats, unmanned underwater vehicles and specially equipped helicopters, for mine warfare, anti-submarine warfare or surface combat. The base configuration would include antimissile batteries and a medium-caliber gun. The ships could clear mines and chase subs away from an area before the rest of the fleet arrived.

REPLACES: Analysts say the LCS is likely to replace 30 frigates and 14 mine-warfare ships.

STATUS: The Navy asked both Lockheed Martin and General Dynamics to create a ship, and the two companies came up

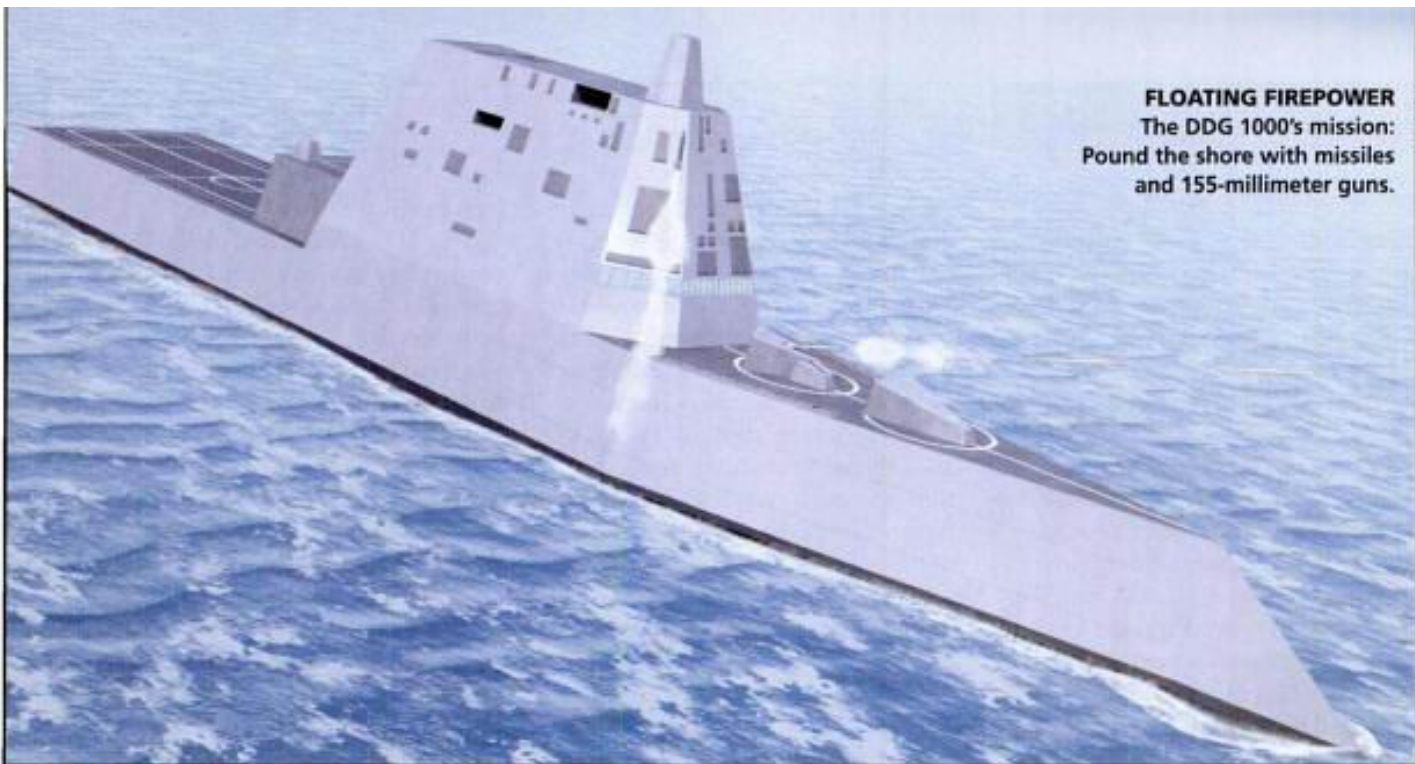
with wildly different designs. Lockheed Martin's USS *Freedom*, or LCS 1, which launched in September 2006, features a semi-planing hull designed to lift partially out of the water for lower friction at high speed. General Dynamics hopes to deliver its high-speed trimaran, the USS *Independence*, by mid-2008.

PROGNOSIS: Iffy. According to a Government Accountability Office report, the Navy changed design requirements as LCS 1 was being built, leading to expensive reconfigurations and pushing costs from an estimated \$472 million to \$1 billion for the pair. The Navy canceled two follow-on ships, and the cost overruns jeopardize the anticipated 55-ship order—and by extension, the entire 30-year plan. As Robert Work of the Center for Strategic and Budgetary Assessments put it, "Until the Navy can prove that it can build affordable ships, it's not clear that we can get to 313."

KRIS HOLLAND

COAST GUARD The small, agile Littoral Combat Ship would specialize in operations near coastlines.





FLOATING FIREPOWER
The DDG 1000's mission:
Pound the shore with missiles
and 155-millimeter guns.

THE DESTROYER (DDG 1000)

PURPOSE: This 14,500-ton destroyer's mission is to pound enemy positions in support of troops onshore. The DDG 1000 features a "tumblehome" hull, which hasn't been used by the world's navies since two major sinkings in the early 1900s. Boosters say the design, which resembles an inverted V, will give the ship a stealthy, low-radar profile by deflecting radar signals skyward. Some critics argue that the broad base of the tumblehome hull makes the ship more likely to capsize in rough seas. But that's up for debate.

"There's a slight advantage to having an angled superstructure, in that your wind moment is actually a little bit less,"

says David McMillan, president of Aker Yards Marine, a commercial-ship design company based in Vancouver. Translation: The same sloping design that helps keep the ship off radar screens should also make it less likely to capsize, because it will present less surface to be pushed over by winds. An electric drive system will create a single source of power for the DDG 1000. Gas turbine engines will create electricity that can be diverted for any task. Under full throttle, the ship's power could be used mainly for propulsion; in battle, that power could be used to fire energy-intensive future weapons such as rail guns, which launch projectiles using magnetic force.

REPLACES: The Navy says the DDG 1000 is a new class of ship and thus won't replace anything older. But some analysts believe it will fill the gap left by the retirement of low-class battleships in the 1990s.

STATUS: The Navy has contracted Northrop Grumman and General Dynamics to each build a DDG 1000. The first, to be launched in 2011, will be the USS *Zumwalt*, and all future DDGs will be called *Zumwalt*-class.

PROGNOSIS: The Navy plans to build seven DDG 1000s, and Congress has approved more than \$6 billion for the two ships already commissioned.

THE MISSILE CRUISER (CG(X))

PURPOSE: The Navy will confirm little about the CG(X) program, but analysts say the ship's job will be to protect a fleet from aerial and missile attack. At least two versions of this ship are being considered. The first could use the same hull as the DDG 1000, replacing one of that ship's guns with additional missile cells and upgrading to a radar system optimized for missile defense. The second could be a larger (23,000 tons instead of 14,500), nuclear-powered ship designed for ballistic-missile defense. Robert Work says that yet another version could provide ballistic-missile defense to the U.S. mainland.

REPLACES: The planned CG(X) will replace the Navy's aging fleet of

MISSILE DEFENSE The CG(X) could be the Navy's next guided missile cruiser.



Ticonderoga-class guided missile cruisers.

STATUS: The Navy plans to order the first CG(X), whatever its final form turns out to be, in 2011. From there, analysts expect the Navy to build up

to a fleet of 19 CG(X)s by 2030.

PROGNOSIS: The fate and eventual configuration of the CG(X) depends on the success of the DDG 1000, as well as on the choice of propulsion.

(CONTINUED FROM PAGE 40)

using electromagnetic catapults and ramps. Radars, infrared sensors and radio-frequency identification (RFID) tags could organize vehicles as they take off and land.

Although it may sound radically new, the UXV actually borrows its basic design from a ship that's already being built: BAE's Type 45 Daring-class destroyer, a stealthy but massive warship set to join Britain's Royal Navy in 2009. Like the Type 45 destroyers, the UXV could measure some 500 feet long and run on diesel-powered electric turbines. Type 45s can reach a top speed of more than 27 knots, or 31 mph; the UXV should clock similar times.

But unlike most of its predecessors, the UXV could run effectively with minimal crew. Battleships once carried hundreds of sailors; the UXV could run with a crew of only 60, enough for three shift changes, along with a handful of additional crew members to service the drones.

Ships take years to build, so to be relevant after 2020, when it's expected

to arrive, the UXV needs to be versatile. That's why BAE engineers, working with the American defense contractor General Dynamics on a separate project, developed a concept they call "modular mission bays," a set of plug-and-play features that would enable commanders to quickly "re-role" the boat. The UXV could change from submarine hunter to mine sweeper to a platform for supplying ground troops to a launching pad for drone-based air strikes.

When they're not in battle, the UXV's various drones would be stored on other ships or land bases; when the UXV receives a mission, the relevant drones would be dispatched to it. For a sub-hunting expedition, the UXV might load up with unmanned underwater vehicles, high-tech radars, torpedoes and even manned aircraft like the Super Lynx sub-hunting helicopter. On a mine-sweeping mission, it would deploy aerial drones to peer beneath the waves and destroy hidden threats. To supply ground troops in battle, it would host troop-carrying landing craft, support-attack helicop-

ters and other armored vehicles.

The UXV should also pack enough heat to give all these assets cover. On the foredeck, missile batteries could house both surface-to-air and ship-to-ship missiles and cruise missiles. A large-caliber gun that fires six-inch munitions, 20 rounds at a time, provides incredible power for ship-to-ship fighting and for strafing a variety of targets onshore. And a 155-millimeter medium-caliber gun would return enemy fire while troops hit land.

When plans for the UXV hit the Web recently, some commenters sniped that the ship was destined to be the warship of a robot uprising. But that's unlikely. As with today's drones, most of the aircraft on the UXV would be controlled by remote human operators. Still, a smaller crew on board and fewer pilots in planes could mean fewer lives lost in almost any battle scenario.

Writer Christian DeBenedetti lives in New York.

THE UXV COMBATANT UP CLOSE

Drones launch from the UXV's next-gen flight deck—and heavy firepower provides cover

NEW-ERA CANNONS

Next-generation cannons could fire bursts of 20 rounds in succession—and have the munitions all arrive on target at the same instant.

SMART WEAPONS

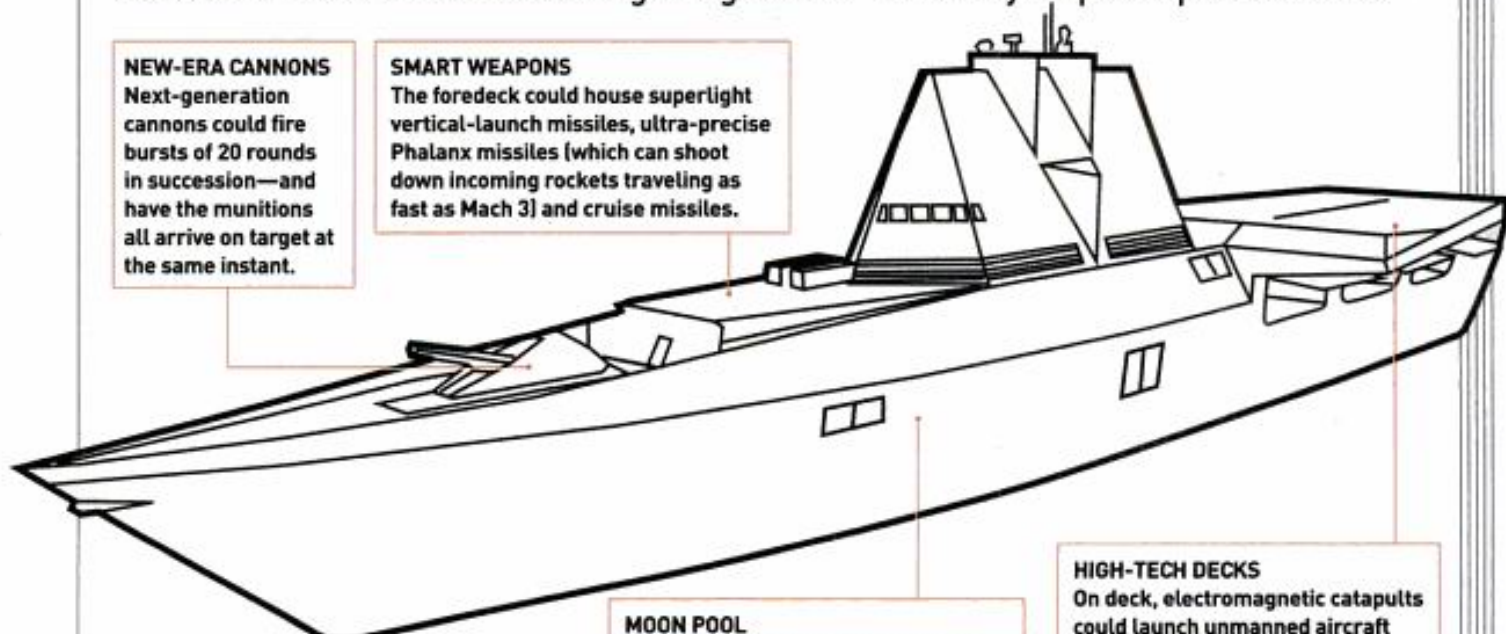
The foredeck could house superlight vertical-launch missiles, ultra-precise Phalanx missiles (which can shoot down incoming rockets traveling as fast as Mach 3) and cruise missiles.

MOON POOL

From a hidden pool in the ship's interior, unmanned subs could deploy and return to the craft safely and invisibly.

HIGH-TECH DECKS

On deck, electromagnetic catapults could launch unmanned aircraft from adjustable ramps. Radar, sensors and RFID chips could be used to organize the drones.



50 GREENEST CITIES
Where Does Your Home Rank? p.51

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YOU DON'T HAVE IT
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POPULAR SCIENCE

**WE BUILT
WHAT?!**

The 20mph
Off-Road
Skateboard



p.73

THE
FUTURE
NOW

REVEALED

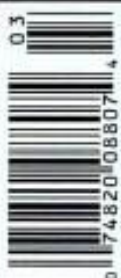
WARSHIPS OF TOMORROW

Inside the Navy's
Secret New Fleet p.38

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MARCH 2008

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HOW IT WORKS

BECAUSE IT'S GOOD TO KNOW WHAT'S INSIDE

YOUR FLAT-SCREEN TV

An LCD TV uses a million crystal switches firing several times a second to create video from a panel barely as thick as this magazine

BY ADAM M. BRIGHT • ILLUSTRATIONS BY GRAHAM MURDOCH

▼ **THE BIG PICTURE:** Liquid-crystal displays (LCDs), whether in your TV, phone or laptop, all create an image the same way: Tiny squares of light—pixels—glow with a particular color and intensity, controlled by liquid crystals sandwiched in between layers of glass a sixteenth of an inch thick. The best sets change pixels so fast that the image never blurs, even in fast action.



**FOR TIPS ON
HOW TO HANG
YOUR LCD TV,
SEE PAGE 101**

BACKLIGHT

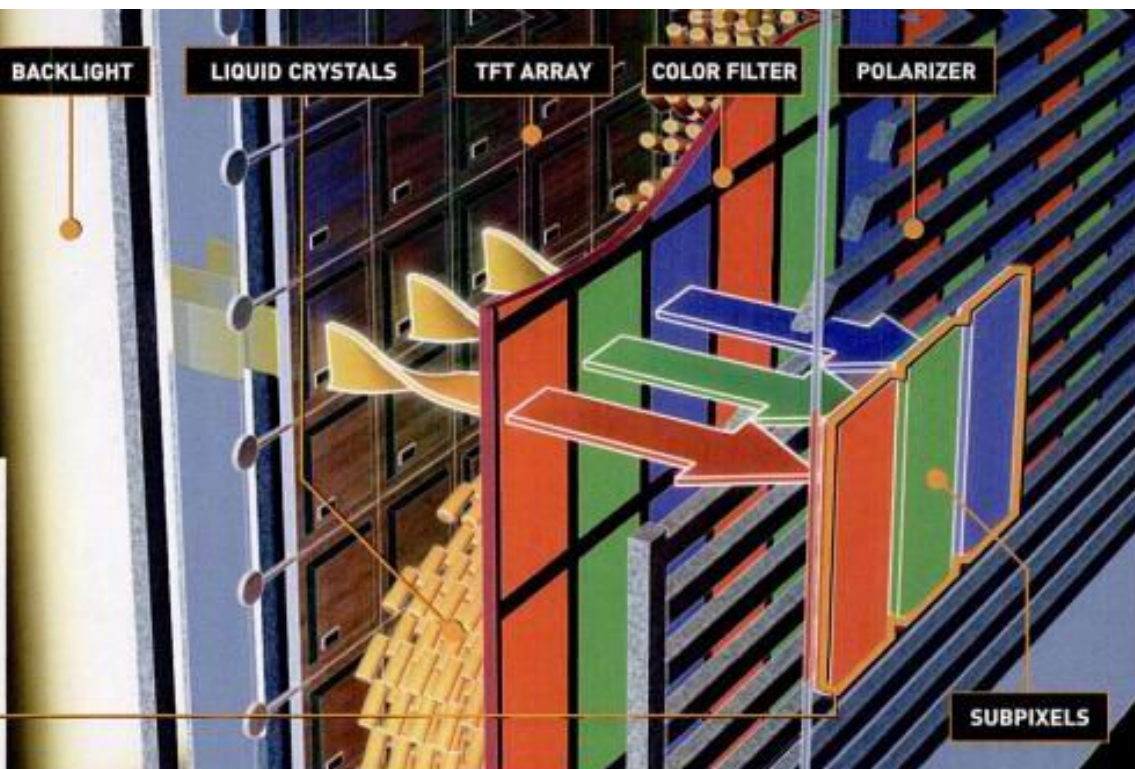
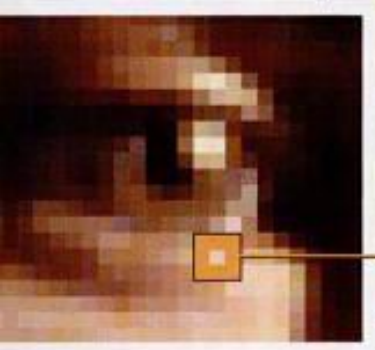
LIQUID CRYSTALS

TFT ARRAY

COLOR FILTER

POLARIZER

► **A MILLION POINTS OF LIGHT** A standard-definition TV has 640 pixels horizontally and 480 vertically—307,200 total. HD sets cram more than two million pixels into a similar-size space for much greater detail.



INSIDE AN LCD: IT'S ALL ABOUT THE LIGHT

1. MAKE LIGHT



A **backlight** created by fluorescent bulbs—or, in the next

generation of LCDs, an array of LEDs—shines through a diffuser to cast a uniform white glow behind the screen. Since light waves naturally orient themselves in all directions, the light first travels through a vertical polarizer to line up all the waves vertically [A].

2. DIRECT IT

The light waves hit the **TFT (thin-film transistor) array**, a sheet of glass with three transistors etched on it for each pixel. Why three? Every pixel on the screen is made up of three smaller blue, red and green **subpixels**. To make a pixel appear, say, purple, only the blue and red subpixels should glow. The TFT controls how much light gets to each subpixel, using information in the TV signal as a guide.

3. TWIST IT



The TFT does this by controlling a layer of **liquid**

crystals. In their natural state, these rod-shaped molecules arrange themselves in a twisted pattern [B], so they turn those vertical light waves horizontal. But when a transistor in the TFT array applies a voltage to the crystals, they line up straight to keep the light vertical.

4. FILTER IT

The light passes through a **color filter** printed on a piece of glass to tint it the proper shade before it hits a **horizontal polarizer**. The twisted light waves get through to make a pixel glow; those that stay vertical don't, leaving that pixel dimmer or dark. A white pixel means all three subpixels are completely lit. This process happens 30 times a second; 60 in a high-def set.

BUYING A TV: WHAT YOU NEED TO KNOW

1. LCD OR PLASMA?

Just a couple years ago, LCD TVs were only cost-effective below 37 inches, and plasma displays were the better bargain for anything larger. But LCD manufacturers can now make bigger sheets of glass more efficiently, enabling not only monsters like the 100-inch at right, but cheaper living-room-size sets as well. Today, you can get a good deal on an LCD up to 50 inches.

2. KNOW THY SIZE

That said, if your set is too large for your living room, you'll not only lose sight of the outer edges, you'll notice every little picture flaw because your eyes will see more of the individual pixels. To figure out the optimum screen height for your space, divide the distance from your couch to the TV by 3.3. Find additional calculators at myhometheater.homestead.com.

3. FIX THY COLOR

Out of the box, LCD TVs have blaring, unnatural colors, meant to look good on a bright showroom floor. To fix them, adjust the brightness until dark areas become as black as possible without losing detail. Then fine-tune the contrast to do the same for white. Set the "temperature" to 6,500 degrees. Finally, adjust the saturation until reds look rich but not too intense.



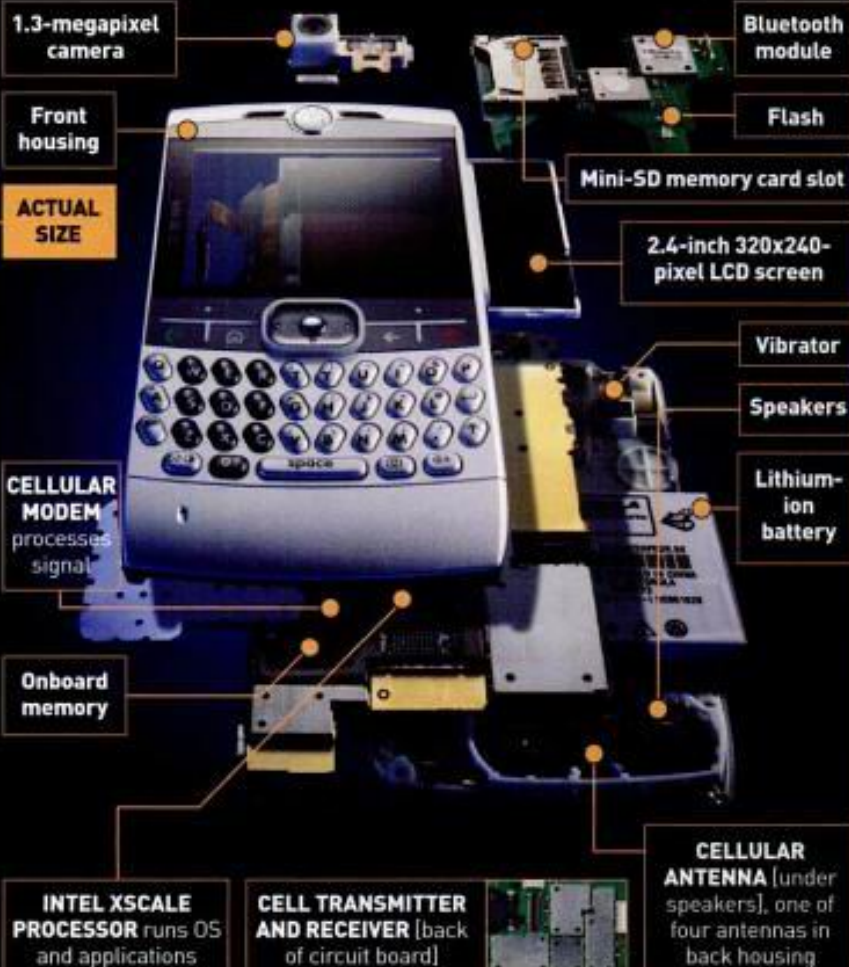
▲ **RECORD SET** The world's largest LCD TV is 100 inches, made by LG.Philips. Put away your wallet: It's not for sale.

THE CIRCUITOUS CELL SYSTEM

HIT "SEND" ON YOUR CELLPHONE, AND THE CALL FOLLOWS A SURPRISINGLY COMPLICATED PATH—INCLUDING MILES ON THE OLD LANDLINES—EVEN TO REACH SOMEONE 10 FEET AWAY. BY JOE BROWN

INSIDE A CELLPHONE

THE NEW 11.5mm-thick Motorola Q smartphone is the thinnest phone ever with a full Qwerty keyboard. Here's how everything fits inside.



1. GETTING A SIGNAL

WHEN YOU TURN ON your cell-phone, it immediately locates itself in the wireless world by broadcasting a series of codes—generally, its phone number, serial number and a code associated with its carrier—to the carrier's closest cell tower. Using the public switched telephone network (PSTN), the system of fiber optics and copper wires landline phones use, the tower relays that information to the carrier's nearest mobile telephone switching office (MTSO). The MTSO—there's at least one for most area codes—then pings back a signal to tell your phone if it's roaming. This exchange happens continuously.

Q: WHAT'S THE DIFFERENCE BETWEEN GSM AND CDMA?

2. MAKING A CALL

WHEN YOU CALL SOMEONE, your phone sends its data as well as the number you dialed to the carrier's nearest tower, which sends it to the MTSO. Before the MTSO connects you, it reserves your call a place on the PSTN. If you're calling a landline, you are directed straight to that phone. If you're calling another cell, the call travels to the MTSO in the recipient's area code.

SPECS: CELLULAR SYSTEM

WHAT: A massive and growing network of towers, copper wire and fiber optics

SIZE: 178,025 towers

CELLPHONE CALLS PLACED EVERY DAY:

About 1 billion

ACTIVE CELLPHONE NUMBERS: Nearly 203 million

AVERAGE TIME IT TAKES FOR A CELLPHONE

CALL TO CONNECT: 4–8 seconds

COPPER LANDLINE

transmits call between switching offices

SWITCHING OFFICE

routes call to recipients' area code

FIBER-OPTIC LINES carry call from tower to switching office

CELLPHONE TOWERS send and receive data from phone

3. RECEIVING A CALL

ONCE CONNECTED, your handset encodes your voice into a digital signal. Because digital signals take up less room than analog on the radio frequencies used by cell towers, each tower can handle more calls at once without a drop in quality.

When the MTSO receives a call for your phone, it establishes a connection through the nearest tower and then sends the call to you. Your phone uses a digital-signal processor to convert the call back into an analog signal—the voice in your ear.

CELLPHONES IN THE U.S. are tied to specific carriers because the U.S. uses different network standards to send calls to and from towers. Cingular and T-Mobile—and most of the world—use GSM (global system for mobile communications), which breaks calls into chunks of time and sequences the snippets so it knows that, say, every third chunk is yours. CDMA (code division multiple access), used by Verizon and Sprint, just embeds each call with its own unique code.—J.B.

THE PERFECT RACECAR

INDY CARS PUSH 230 MPH, HUG HAIRPIN TURNS, AND BRAKE FEROCIOUSLY. WE TOOK APART DRIVER BRYAN HERTA'S CAR TO FIND OUT HOW BY ERIC ADAMS AND JOE BROWN

ANDRETTI GREEN TEAM CAR

AERODYNAMICS

Front and rear carbon-fiber **WINGS** (1)—essentially upside-down airplane wings—push the car down onto the track so it sticks like glue even at 230 mph. The large three-element wings shown here are for short road courses, which are slower and have more turns. On fast tracks, such as the Indianapolis Motor Speedway, smaller wings provide the same down-force with less drag.

FRONT AND REAR WING PANELS adjust to balance handling and to meet league speed mandates.

Energy-absorbing head surround

CUSTOM-MOLDED SEAT fits only Bryan Herta's posterior

CRASH BOX relays severity of the wreck to emergency crews

Foot pedals

Control arm

ENGINE-CONTROL MODULE sets fuel flow and spark-plug firing so the driver can choose between power and fuel economy

BRAKE ROTORS include multiple paint patches that change color at set intervals—430, 560 and 610 degrees—signaling the pit crew that the brakes might be overheating



SPECS: INDY CAR

VEHICLE: Andretti Green Racing #7

DIMENSIONS: 38 in. (h) x 78.5 in. (w) x 192 in. (l)

WEIGHT: 1,525–1,600 pounds

0–100–0 MPH: Under 5 seconds

COST TO RUN PER SEASON: \$7.5 million

HANDLING

Upper and lower **CONTROL ARMS (2)** connect the wheel to the chassis. Even they are aerodynamically optimized, with a teardrop-shaped cross section. Adjustable, super-stiff, nitrogen-filled **SHOCKS (3)** prevent body roll while cornering. Unlike a commercial car's vertical shocks, they mount horizontally to minimize drag.

Gearbox

DRIVETRAIN

Every Indy car uses a methanol-fueled 3.0-liter, 650hp **Honda V8 ENGINE (4)** with a maximum rpm of 10,300. A **SCOOP (5)** feeds air into a cone-shaped intake, called a trumpet, above each cylinder. The 10-quart oil case lies directly behind the engine instead of beneath it so that the engine can sit lower, giving the car a sleeker profile and a lower center of gravity. A six-speed **SEQUENTIAL GEAR-BOX (6)** engages only the next gear up or down; drivers can't skip gears. The system is tuned to favor sustained top speed over acceleration, enabling the car to maintain speeds of 230 mph.

Air scoop

Honda V8 engine

Wing

FUEL RESERVOIR, made of rupture-proof Kevlar and rubber, sits just behind the driver

Shock absorbers

UNDERTRAY with oil-absorbing liner

RADIATORS cool both engine and oil

FIRESTONE FIRE-HAWK TIRES are 10 inches wide up front to minimize rolling resistance and 14 inches in back to boost grip

CARBON-FIBER CHASSIS is built in Italy by Dallara

HOW YOUR TIRES GET A GRIP

Tires grip the road because their malleable rubber compound almost instantaneously fills in microscopic imperfections in the concrete or asphalt. The more rubber on the ground, the better the traction. Snow tires have slits that actually hold onto snow, providing grip through natural snow-on-snow friction.—E.A.

MYSTERIES OF EVERYDAY LIFE*

THE MOST ADVANCED FLIGHT DECK

THE WORLD'S BIGGEST AIRLINER ALSO HAS THE SMARTEST COCKPIT, WITH SCREENS THAT SHOW MORE AND MAKE IT EASIER TO FLY BY BILL SWEETMAN

NEW ON THE A380

1 PRIMARY FLIGHT DISPLAY is larger than older versions and shows multiple streams of information, including digital instrumentation, deftly prioritized for the pilots.

2 NAVIGATION DISPLAY registers course changes graphically when the pilot programs new waypoints. A vertical situation display shows a side profile of the flight path relative to the terrain, providing a more intuitive reading of the ground.

3 MULTIFUNCTION DISPLAY allows pilots to enter navigation data and radio frequencies and to communicate with flight controllers.

4 ENGINE WARNING SYSTEM alerts pilots to engine and fuel-system problems.

5 HEAD-UP DISPLAY [not shown] projects data onto a retractable screen, and an optional infrared view sees through darkness and fog during takeoff and landing.

6 SIDESTICK HAND CONTROLLERS move the wings and tail. Placing them on the side (instead of in the center) leaves room for a full keyboard.

7 ONBOARD INFORMATION SYSTEM displays maps and manuals and, while taxiing, runway diagrams.

SPECS: A380

SIZE: 239 feet long,
261-foot wingspan
PASSENGERS: 555
COST: \$295 million (est.)

AIRBUS A380 COCKPIT

AUXILIARY POWER UNIT CONTROL
starts main engines

Magnetic compass

Autopilot controls

INSTRUMENT BACKUPS, in case primary screens fail

Vertical situation display

Engine control

NAVIGATION and flight data input

Radio controls

Collision-avoidance system

SPEED BRAKE, used in flight

Parking brake

HOW THE A380 GETS MORE POWER WITH LESS NOISE

The four massive 70,000-pound-thrust high-bypass turbofan jet engines driving the A380 will actually be quieter than the engines on many smaller planes. That's because high-bypass engines employ carefully sculpted blades and wider fans (116 inches in the A380's Rolls Royce model) to accelerate more air past the engine core and out the rear, allowing the engines to operate more slowly and quietly without sacrificing thrust. —B.S.



MYSTERIES OF



Hydraulic-system controls

Fuel-system controls

Electrical-system controls

Cabin pressure/climate control

Landing gear

Nose wheel steering

Rudder pedals and brakes

FLAPS change wing shape for slower flight

Cockpit door lock controls

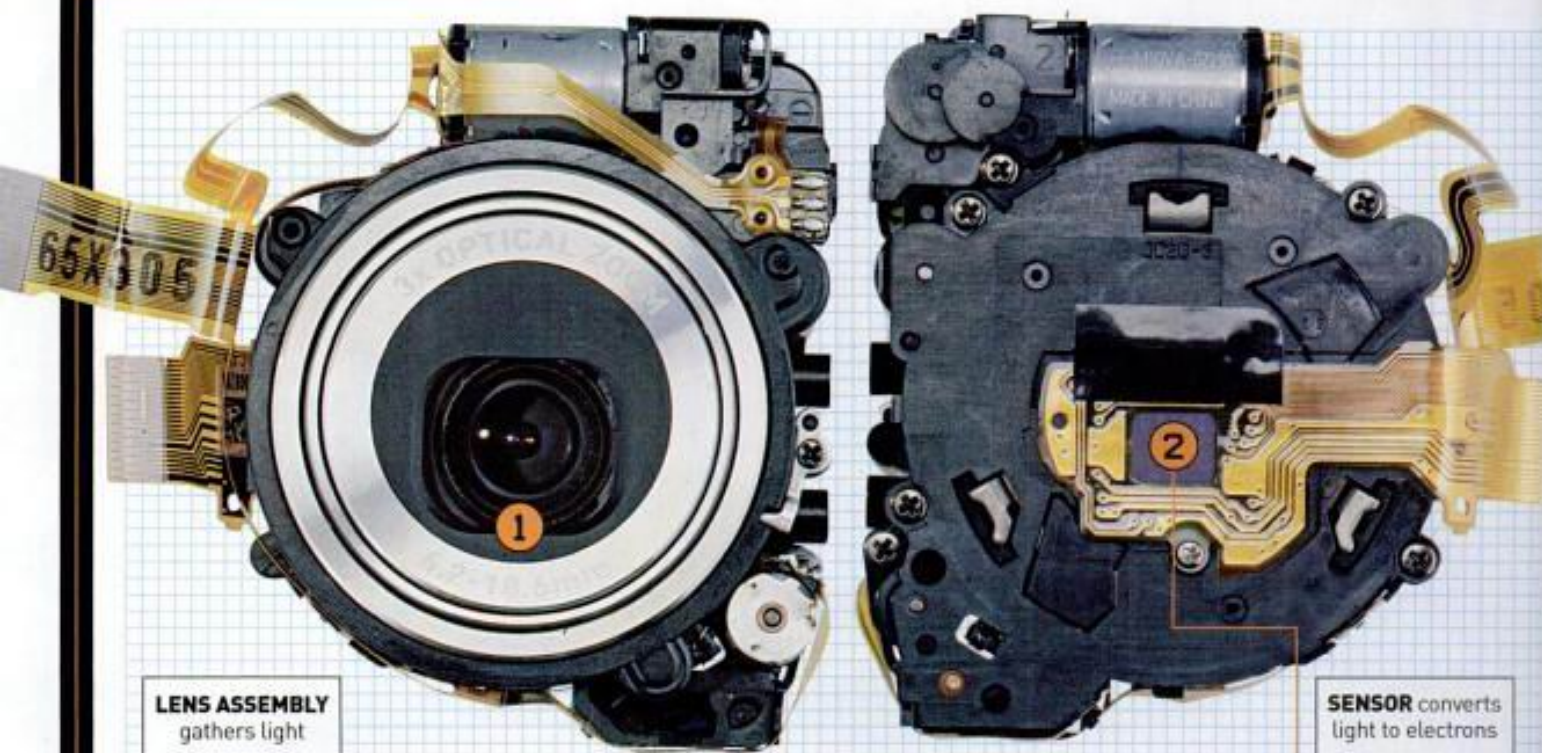
Trim settings

EVERYDAY LIFE*

THE THINNEST CAMERA

HERE'S HOW POCKET-SIZE DIGITAL CAMERAS PULL OFF A HUGE FEAT: TURNING SIX MILLION BITS OF LIGHT INTO A PHOTO IN BARELY A SECOND BY JACKSON LYNCH

CASIO EX S600BE



LENS ASSEMBLY
gathers light

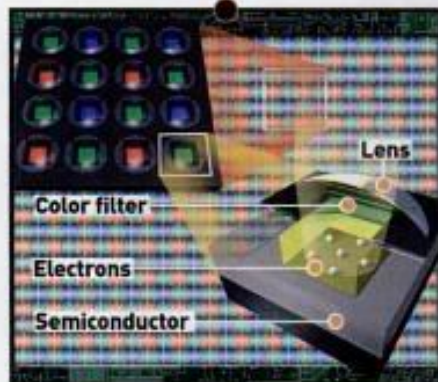
SENSOR converts
light to electrons

1. FOCUS

THE LENS ELEMENT comprises many tiny lenses stacked on top of one another. They lie together tightly when the camera is off, but a small motor extends them when you turn it on and when you adjust the zoom. The lenses work in tandem to precisely gather and focus light onto the image sensor as directly as possible. If light hits at an oblique angle, the sensor won't record it properly, and your shot will be fuzzy. No matter how advanced the rest of the camera, a shoddy lens will always make shoddy pictures.

2. RECORD

MOUNTED DIRECTLY BEHIND the lens, the CCD (charge-coupled device) sensor is a rectangular array of millions of individual light-sensitive photo sites—one for each pixel—that translate photons into electrical charges. Another very small lens is mounted over each photo site, along with a red, green or blue filter, which determines the color of the light. Each pixel's electrical energy is tallied row by row and moved into the analog/digital converter, which changes it into a digital signal of 0s and 1s.



At each pixel, light travels through a tiny lens and a color filter before collecting on a semiconductor called a photo site.

Q: HOW DO

SPECS: CASIO EX S600BE

WHAT: Thinnest 6-megapixel camera available

SIZE: 2.32 in. (h) x 3.54 in. (w) x 0.63 in. (d)

WEIGHT: 4 ounces **COST:** \$400

SENSOR: 0.4-inch-square primary-color CCD containing 6.18 million pixels

LENS: 6 lenses in 5 groups, F2.7 to F5.2 (equivalent to approximately 38mm to 114mm)

MAX. SIZE OF PRINT-QUALITY PHOTOS: 11 x 14 in.

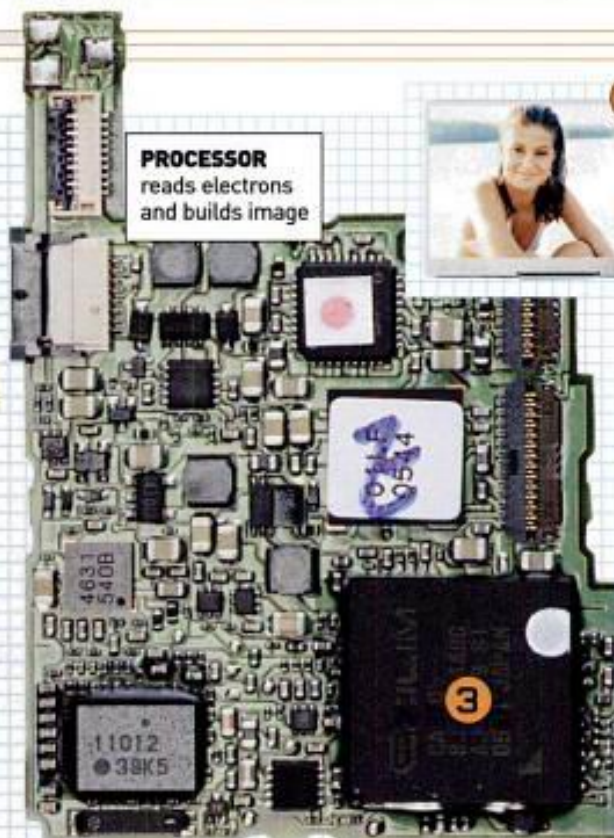
NUMBER OF SHOTS PER CHARGE: 300

MORE INFO: casio.com

TIP: STEADY ON

Smaller cams are even harder to hold steady.

Many now include digital optical stabilization, in which the DSP looks for the telltale signs of a shaky shot and tries to fix the jittered pixels. Still, nothing beats using a tripod. See how to make your own on page 86.



3. PROCESS

NEVER MIND THE NUMBER OF PIXELS—if the information coming from them isn't processed correctly, your image will suffer. The digital-signal processor (DSP) refers to both the circuitry and the software that applies the camera's instructions to the recently arrived digital data and then assembles an image. After you snap a picture, the DSP examines each pixel's color value in relation to the values of its neighboring pixels to accurately determine its true hue. For example, if a red pixel is very bright and all the green and blue values near it are also very bright, then it's most likely a white pixel. The DSP also gathers information before you press the shutter and uses that to more accurately process the image.

4

4. DISPLAY

THE CASIO'S LCD is a typical thin-film transistor (TFT) display that sandwiches a rectangular arrangement of thousands of red, green and blue pixels beneath layers of liquid crystals and multiple layers of glass. The image information arrives here from the DSP, so you can immediately review it.

5. SAVE

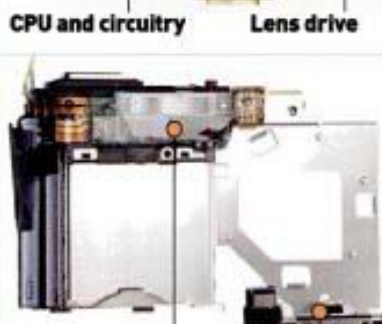
A FLASH-MEMORY CARD

like the SD card in the Casio, stores data in a system of gated transistors called cells, which are opened and activated by the voltage of the signal from the DSP. Denser cells mean more memory. A six-megapixel photo uses about two megabytes of memory.



13.7mm-thick stainless-steel case

FRONT VIEW



Flash and strobe unit Battery frame

REAR VIEW



CCD sensor Memory-card slot



354x240-pixel, 2.2-inch LCD screen

HD CAMCORDERS CAPTURE VIDEO?

HD CAMCORDERS use sensors that capture up to three megapixels 60 times a second but add a second sensor layer and shift half the captured data to it for processing. This creates an interlaced video: Half the pixels are onscreen in one frame, the other half in the next, and your eye puts them together. —DARRIN BURGESS

RUGGED BOTS ON MARS

Scientists propose a mission to explore Martian valleys too dangerous for ordinary rovers

NASA'S CHAMPION MARS ROVERS *Spirit* and *Opportunity* have explored almost eight miles of Martian plains, but the six-wheeled robots are no match for the treacherous Valles Marineris, a 2,500-mile expanse of canyons, many of which are up to seven times as deep as the Grand Canyon. Potentially teeming with ancient flood channels—and possibly signs of life—the valley is high on NASA's list of must-see destinations. Now physicist Wolfgang Fink of the California Institute of Technology and geologist James Dohm of the University of Arizona have proposed a radical way to explore such rocky, steep terrain. Their solution is an autonomous army of orbiters, blimps and cliff-scaling robots. Orbiters would circle the planet, guiding the robots to possible astrobiological sweet spots, such as methane plumes, while the blimps would hover closer to the ground, exploring features too small for the orbiters to see clearly. Fink hopes to test a prototype system in Arizona within two years and launch it by 2020. —KAREN HEYMAN

1. GETTING THERE

Fink proposes a single launch to save costs. Miniature rovers and lightweight blimps will keep the mission weight under five tons, which is comparable to the payload weight of many of today's orbital missions.

2. SPACE ORBITERS

Orbiters similar to NASA's *Mars Global Surveyor* would conduct broad-range reconnaissance missions from hundreds of miles above the ground. Once they spot an area of interest, they will command the blimps to take a closer look.

3. AIR PATROL

Fink envisions using helium-filled, solar- and battery-powered blimps equipped with high-resolution cameras and infrared sensors to guide the rovers through narrow canyons. Stationed closer to the ground than the orbiters, the blimps would also act as intermediary communication links between the rovers and the orbiters. This will reduce the power demands on all the equipment, Fink says.

4. MINIATURE ROVERS

Deploying dozens of miniature rovers instead of two larger ones ensures that the mission won't die if a few break down. The proposal calls for different rovers for different types of terrain—spider-like robots, for instance, could scale cliffs and drill out samples; tiny-wheeled bots could explore cracks and crevices.

DATA RELAY

The biggest challenge is not so much the hardware but the software that would enable all the components to function autonomously. Fink and his team are now developing algorithms that would enable the orbiters, blimps and rovers to communicate with one another and navigate the terrain without help from mission control.



CONTINUED FROM PAGE 29

features a number of mechanical advances, including five independently moving fingers. A DC motor in each digit gives the robotic hand 16 degrees of freedom, so it can move in a variety of subtle directions (the human hand has 22 degrees of freedom). Each motor pulls a Teflon-sheathed cable that mimics actual tendons and muscle in the fingers, enabling them to curl around a coffee mug, for instance. With pressure sensors embedded along the surface of the fingers, the hand can pick up even delicate objects without crushing them.

The hand's computer will act as a man-machine interpreter.

Although the primary goal of the Cyberhand is to make patients feel as if they have their limb back—that is, to design a fully functional hand that moves in perfect sync with the wearer—engineers are also paying close attention to aesthetics. "When we hear from patients, they say they're almost ashamed of using the kind of pincher mechanisms that are on the market," says Lucia Beccai, the project's manager. For that reason, the entire mechanism will be encased in a silicone cosmetic glove made to look like a real human hand, down to the fingernails. The hope is that it will "look and feel more natural for the patient, so it will feel less like an external part of the body," Beccai says.

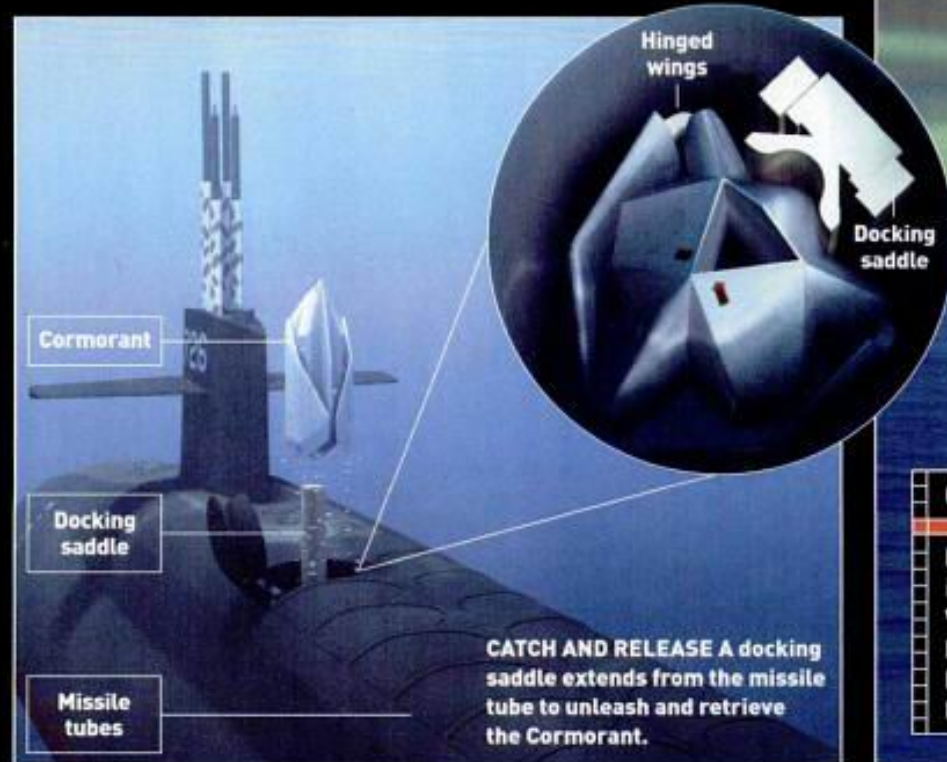
Obviously, the technology is not quite at the stage where a Luke Skywalker type can get his hand lopped off and simply head down to the droid department for a flawless replacement. Beccai expects that it will be another five to eight years before the Cyberhand even goes on sale, but she's confident that the Star Wars era is on the horizon. "This is truly a great moment for enhanced prostheses," she says. "With smaller motors and new sensors, big change is going to happen in a relatively short time." —BILLY BAKER



ILLUSTRATION: GRAHAM MURDOCH

THE NAVY'S SWIMMING SPY PLANE

It floats, it flies, it eliminates enemy targets—meet the water-launched unmanned enforcer



CORMORANT

PURPOSE: To spy on or eliminate targets identified by naval intelligence

WINGSPAN: 16 feet

MAXIMUM SPEED: 530 mph

RANGE: 1,150 miles

MAXIMUM ALTITUDE: 35,000 feet

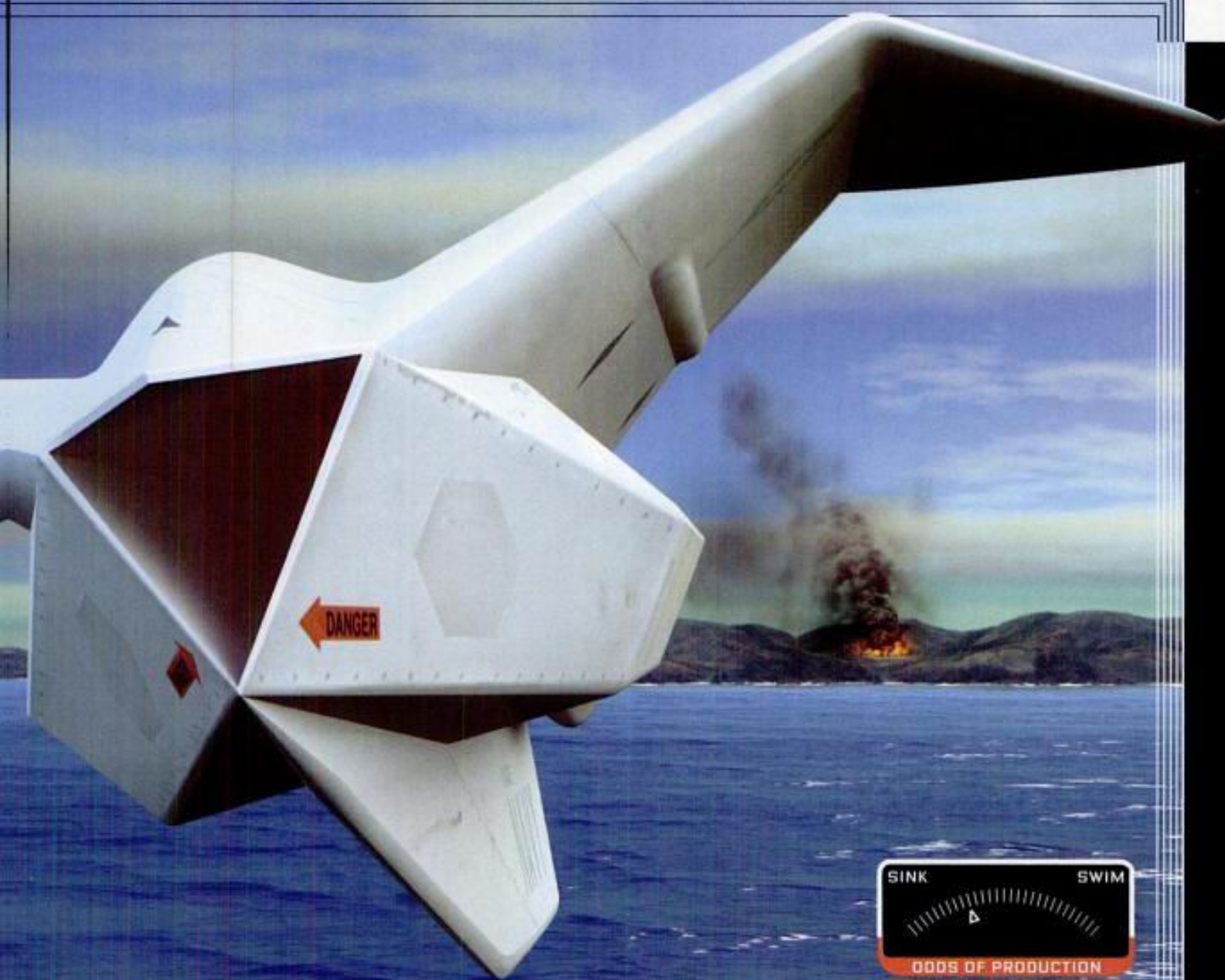
LOCKHEED MARTIN'S Skunk Works, famed for the U-2 and Blackbird spy planes that flew higher than anything else in the world in their day, is trying for a different altitude record: an airplane that starts and ends its mission 150 feet underwater. The Cormorant, a stealthy, jet-powered, autonomous aircraft that could be outfitted with either short-range weapons or surveillance equipment, is designed to launch out of the Trident missile tubes in some of the U.S. Navy's gigantic Cold War-era Ohio-class submarines. These formerly nuke-toting subs have become less useful in a military climate evolved

to favor surgical strikes over nuclear stalemates, but the Cormorant could use their now-vacant tubes to provide another unmanned option for spying on or destroying targets near the coast.

This is no easy task. The tubes are as long as a semi trailer but about seven feet wide—not exactly airplane-shaped. The Cormorant has to be strong enough to withstand the pressure 150 feet underwater—enough to cave in hatches on a normal aircraft—but light enough to fly. Another challenge: Subs survive by stealth, and an airplane flying back to the boat could give its position away.

The Skunk Works's answer is a four-ton airplane with gull wings that hinge around its body to fit inside the missile tube. The craft is made of titanium to resist corrosion, and any empty spaces are filled with plastic foam to resist crushing. The rest of the body is pressurized with inert gas. Inflatable seals keep the weapon-bay doors, engine inlet and exhaust covers watertight.

The Cormorant does not shoot out of its tube like a missile. Instead an arm-like docking "saddle" guides the craft out, sending it floating to the surface while the sub slips away. As the drone pops out of the water, the rocket



PopSci
ON THE WEB

See more pictures at
popsci.com/cormorant.

boosters fire and the Cormorant takes off. After completing its mission, the plane flies to the rendezvous coordinates it receives from the sub and lands in the sea. The sub then launches a robotic underwater vehicle to fetch the floating drone.

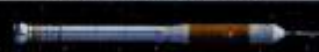
The Defense Advanced Research Projects Agency (Darpa) is funding tests of some of the Cormorant's unique systems, including a splashdown model and an underwater-recovery vehicle. The tests should be completed by September, after which Darpa will decide whether it will fund a flying prototype.

—BILL SWEETMAN

▲ **ROBO HITMAN**
The Navy could deploy the Cormorant to take out targets identified by SEAL teams.

▶ **BLAST OFF**
Two rocket boosters would burn for about 12 seconds during takeoff while the jet engine spun up to running speed.





Earth departure stage

THE JOURNEY BEGINS

NASA's Crew Exploration Vehicle, carrying four astronauts, will dock in low Earth orbit with a lunar lander and a rocket stage. The completed spacecraft will then head for the moon.

Service module

Earth departure stage

Lunar descent stage

Lunar ascent stage

Lunar lander

Crew capsule

Service module

NASA'S NEW RIDE

Roomy, reliable and affordable, the Crew Exploration Vehicle will be a Toyota Camry for space **BY WILLIAM SPEED WEED ILLUSTRATIONS BY BOB SAULS**

They're alive already, the Fantastic Four, and it's fun to wonder who they might be. They're in their 20s now, smart and ambitious. One might be an engineering student cramming for his finals; maybe a pilot flying sorties over Iraq; or an intern on the ER graveyard shift. In a dozen years or so, they'll strap themselves atop a rocket packing 1.1 million pounds of solid propellant that will hurtle them, pulling 4.5 Gs, to 250,000 feet. A sec-

ond rocket stage will then boost them into low Earth orbit, where they'll dock with another rocket that will shoot them into orbit around the moon. Leaving their spacecraft to be tended by computers, all four will climb into a lunar lander and descend to the moon's surface. They'll don their space suits, open the hatch, and make that giant leap once again.

This is no nostalgia trip, though. The Fantastic Four will have a sophis-

ticated spacecraft and a mission that Neil and Buzz could only dream of.

LONG TIME COMING

The moon will have circled the Earth some 600 times between the departure of *Apollo 17* in 1972 and the arrival of these four guests in 2018, NASA's target date. That's 46 years of treading water, never flying beyond low Earth orbit. Only 12 humans set foot on the moon during the Apollo

era, and there are vast areas yet to be explored. Scientists believe that some have frozen water hidden beneath the surface, which would be valuable for establishing a human outpost and manufacturing rocket fuel. We could also use the moon as a training ground for crews preparing for the much longer trip to Mars, the planet most like Earth and therefore of greatest interest to scientists and would-be colonists alike.

But sending humans back into outer space has proved tougher than any rocket science. Since the end of the Cold War, the U.S. government has

been unwilling to expend the substantial capital needed to go to the moon and on to Mars, as proposed by both Presidents Bush. What we've lacked is a vehicle that can get there *and* be safe *and* be affordable. Now, thanks to an aggressive push by NASA Administrator Michael Griffin, the space agency finally has a design for such a spacecraft, called the Crew Exploration Vehicle, or CEV.

This month, working off detailed NASA requirements, Lockheed Martin and a Northrop Grumman-Boeing team will submit proposals to build

the CEV. NASA will award the contract this summer, and the CEV should make its first orbital flight in 2012—perhaps a visit to the International Space Station, some 240 miles overhead. If the craft proves as capable and cost-effective as Griffin promises, the space agency will outfit it for a 240,000-mile flight to the moon. The CEV is a modular system, so engineers can eventually add expanded life-support and crew-living modules for the long trip to Mars—more than 35 million miles away—sometime after 2020.

How does Griffin plan to accom-

FLIGHT PLAN

A trip to the moon will require two launches and two stops along the way—in Earth and lunar orbit

RENDEZVOUS

The unmanned heavy-lift launch vehicle carries the lunar lander and Earth departure stage into Earth orbit. A few days later, a crew-launch vehicle lifts the crew capsule and service module into the same orbit (1).

DEPARTURE

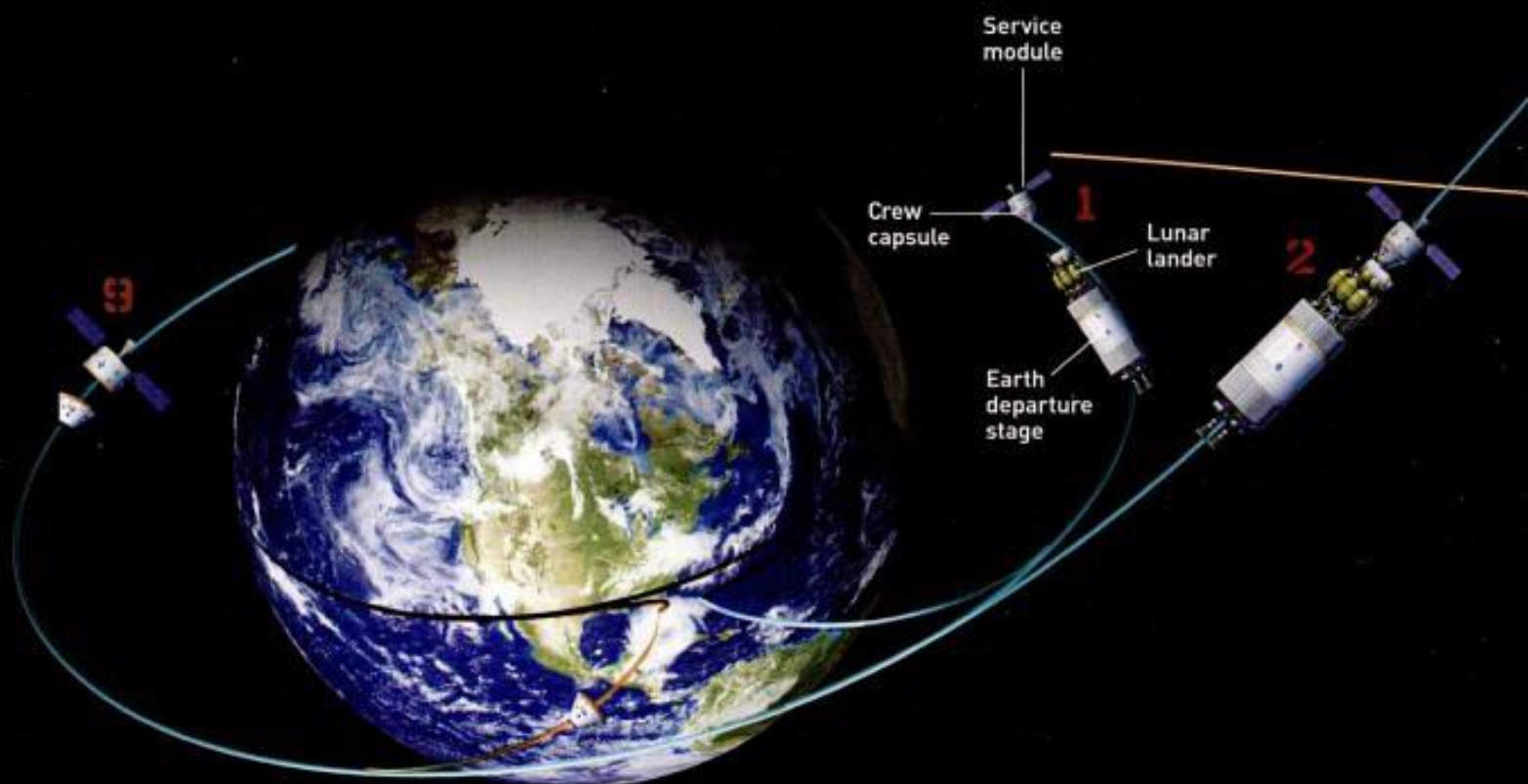
The capsule and service module dock with the lunar lander and Earth departure stage, and the rocket stage fires to send the entire spacecraft to the moon (2). The spent rocket is then discarded (3).

ARRIVAL

While their spacecraft is orbiting the moon, all four astronauts climb into the lunar lander, which then detaches and descends to the moon's surface (4). The astronauts spend up to six months exploring the lunar surface (5).

RETURN

To head back home, the lunar ascent stage blasts off from the bottom half of the lander (6) and rejoins the orbiting spacecraft (7). The ascent stage is jettisoned, and the crew heads back to Earth (8). In Earth orbit, the crew capsule separates for reentry (9).



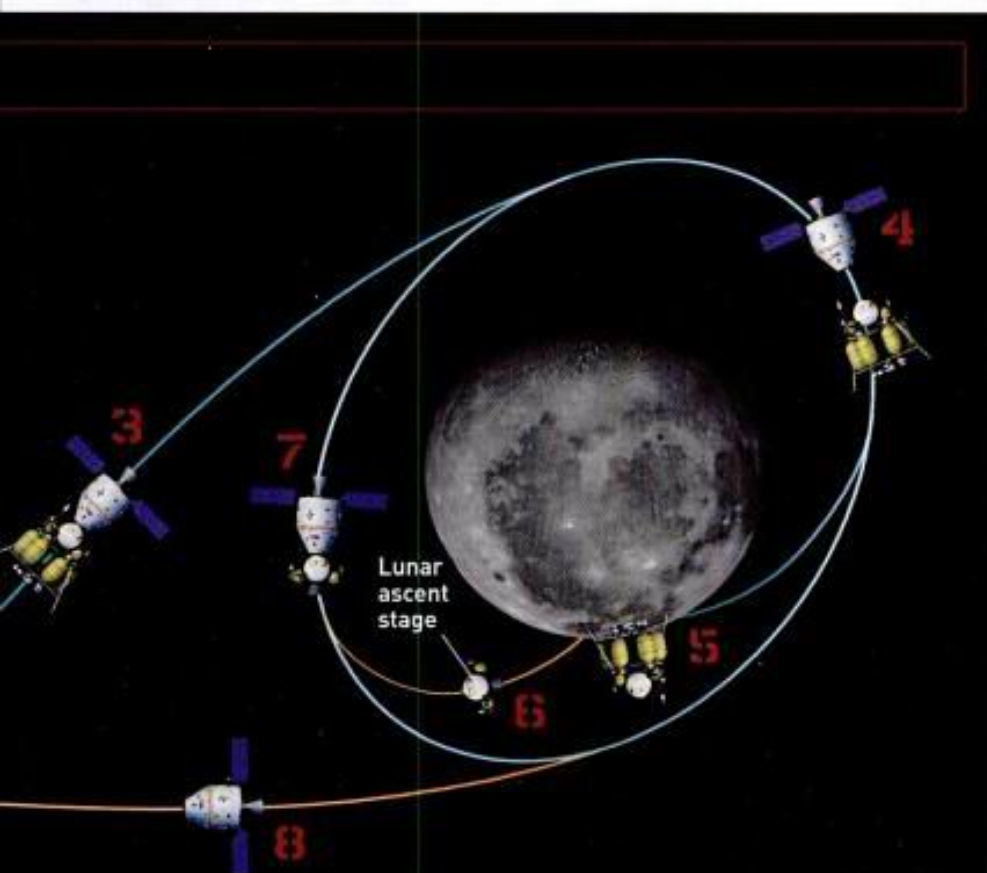
plish all this? With a wildly tame approach: Don't innovate. The CEV revolution is to have no revolution, play it safe, stick to what you know. The CEV will be an amalgam of Apollo's shape, the space shuttle's rockets, and a host of newer components built for unmanned satellites. This is a marked departure for NASA. The shuttle and Apollo were intensely innovative programs, but the CEV is purposely not, because innovation in spaceflight is the primary driver of risk and expense. NASA specs out the CEV at \$104 billion over 13 years—or 55 percent of Apollo's cost, adjusted

for inflation—and pegs its reliability at a 1 in 2,000 chance of failure, 10 times as safe as the shuttle.

"We're not looking at what's the latest and greatest, but at what's proven, technologies that have a track record," says Leonard Nicholson, CEV deputy program manager for the Northrop Grumman-Boeing team. "What's really radical in this is the capability of the sum of its parts." Like a responsible dad, Griffin is buying the Toyota Camry instead of going for the Porsche. Still, it's a pretty cool Camry—this one flies to the moon.

THREE KEY FACTS

- 1 NASA is reverting to Apollo-era designs** for the next-generation crew vehicle but using modern systems and hardware.
- 2 Although the CEV won't carry the same loads as the shuttle**, it is more versatile and less expensive.
- 3 When astronauts visit the moon aboard the CEV**, nobody will have to stay in lunar orbit to monitor the command module—the entire crew will visit the surface.



IT'S ABOUT LAYING A GROUNDWORK FOR AN EXTENDED PRESENCE IN SPACE, ON THE MOON AND, ULTIMATELY, FOR MISSIONS TO MARS.

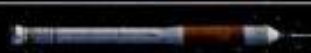
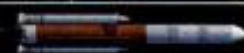
ECHOES OF APOLLO

When our four lunar astronauts launch in 2018, their command module will be a capsule that old-timers could well confuse with Apollo. "Much of it looks the same," Griffin said in a recent press conference, "but that's because the physics of atmospheric entry haven't changed." In an extensive study last summer, NASA looked at all spacecraft designs known to engineering and, Griffin said, "proved once again how much of it all the Apollo guys got right."

The astronauts will find their capsule much roomier than Apollo, and they will have had a major hand in designing the interior. A team of astronauts, scientists and engineers is already experimenting with a rudimentary mock-up of the crew capsule, deciding where to put the doors and windows, the seats and consoles.

Just under the conical crew capsule on the launch stack will be the CEV service module, a cylindrical fairing that houses rocket engines and power systems. NASA wants the service module's rockets to be powered by liquid oxygen and liquid methane, or "lox-methane," because both of these ingredients could theoretically be extracted from the soil on Mars—allowing astronauts to fly there without having to carry fuel for their return trip.

Lifting the crew and service modules into space will be the crew-launch



vehicle, a two-stage rocket. The first stage is a solid rocket booster borrowed from the space shuttle, which gets its initial lift from a pair of such boosters strapped to each side of its massive orange fuel tank. The solid rocket booster is one of the most reliable pieces of space machinery ever built and is already approved for human transport. Like the shuttle's main engines, the second stage of the crew's launch rocket burns a combination of liquid oxygen and liquid hydrogen.

Because the CEV and its crew ride

on top of the rocket rather than strapped to its side like the shuttle orbiter, they can't get hit by falling debris. That's one of two reasons NASA expects the CEV to be so safe. The other reason is the launch-abort system, a rocket attached to the nose of the CEV that will fire if the solid booster explodes on liftoff—pulling the CEV away from the exploding rocket so that it can safely parachute into the ocean.

Once in space, the CEV is not a satellite-launching, station-building truck like the shuttle. It is simply a taxi

that goes from point A to point B—but a very capable taxi. "It's overqualified for the International Space Station, but it can certainly go there," says Brian Anderson, the acting manager for the CEV at NASA's Johnson Space Center in Houston. It can carry six astronauts or deliver cargo to the station robotically.

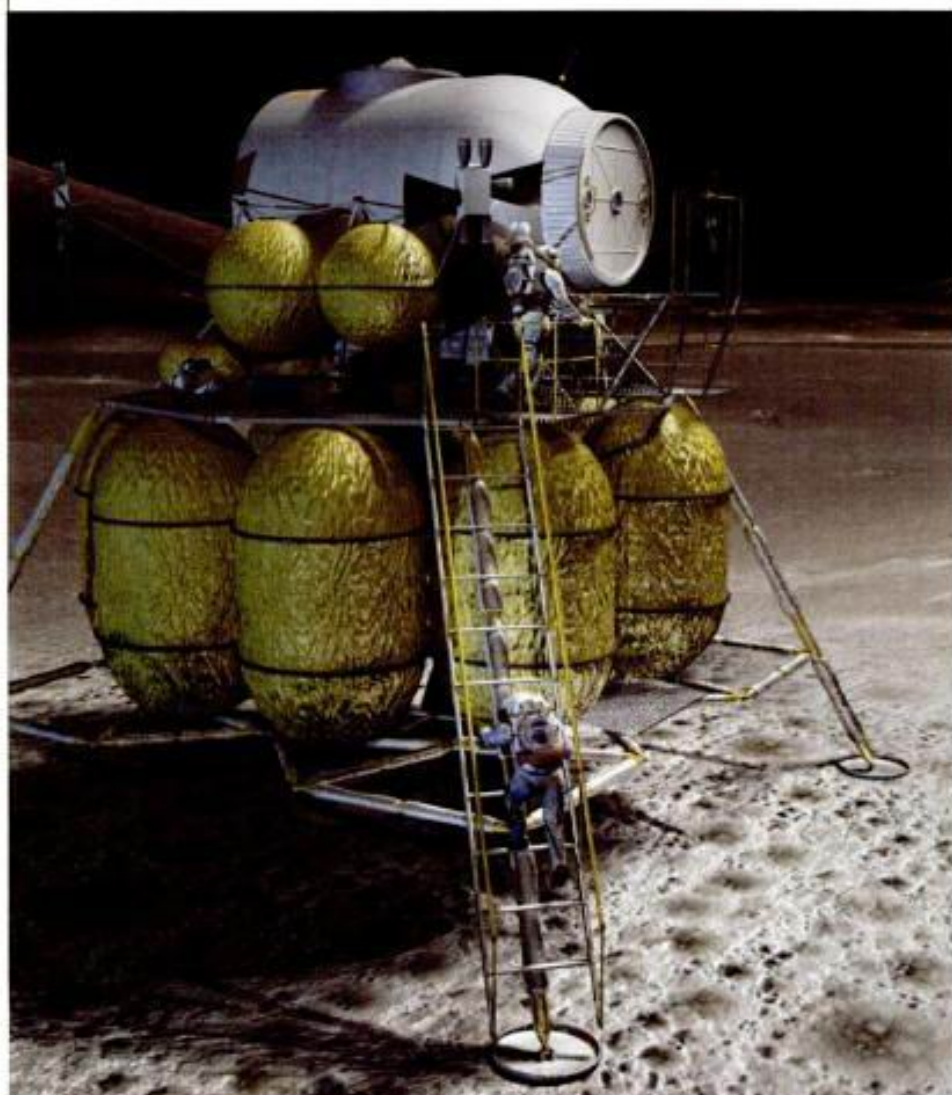
The CEV lacks the thousands of tiles that protect the shuttle from heat. Rather, its heat shield is tucked inside the service module until reentry, so it isn't exposed to micrometeorite damage while in space. After friction slows the descending spacecraft, the CEV capsule will fire its parachutes for the final approach. Anderson's CEV team is already designing these chutes and plans to do its first test-drops this month. "Our motto is 'Test early and test often,'" Anderson says. "We cannot fly in 2012 without bending metal today."

THE MOON, THEN MARS

A trip to the moon will require additional hardware. A few days before the crew-launch vehicle releases the CEV, a much larger heavy-lift launch vehicle, also derived from the shuttle, will pre-position a lunar lander and Earth departure stage rocket in low Earth orbit. The CEV will maneuver to dock with these two modules, and then the conjoined spacecraft will use the Earth departure stage's rocket to fly to lunar orbit. All four crew members will then board the lunar lander, detach from the CEV, and descend to the moon's surface.

NASA hasn't yet decided what the astronauts will do on the moon. They may look for frozen water at the lunar south pole or scout out other potential locations for a lunar base. They may test methods and materials for constructing habitats on the moon. Former NASA historian Roger Launius, now at the Smithsonian Institution, envisions outposts similar to Antarctic research stations. Whereas stations at Earth's windy South Pole are concrete, those on the windless moon could be built with inflatable materials and powered by nuclear generators.

The CEV "allows us, but does not require us, to establish a permanent



TEMPORARY MOON BASE



What the astronauts will do on the moon is still a bit speculative. The first lunar missions will be four days to a week, but the CEV is being designed to orbit autonomously for up to six months while astronauts remain on the moon's surface. One scenario calls for sending astronauts to the lunar south pole to look for frozen water, a commodity required for establishing a lunar base.

human presence on the moon," Griffin says. He clearly wants to "scar in" flexibility for the next guy: If the moon is interesting to the NASA administrator in 2020, CEV will allow him to build a base. If he's itching to get on to Mars, the CEV could fit the bill.

Of course, there's a lot of engineering that will be required before a Mars shot can happen, especially in the areas of life support and radiation protection. A trip to Mars isn't likely until well past 2020, and at that point the CEV will already be more than 10 years old. But NASA and its aerospace contractors say the CEV won't suffer the problems of obsolescence that have plagued the shuttle. The CEV is more a set of technical designs than an actual fleet. That makes it easier for later iterations of the vehicle to incorporate updated technology.

HURDLES REMAIN

Some enthusiasts would prefer to skip the moon and go straight to Mars. Others ache to push the limits of technology and invent something new. But it's hard to argue with reliability, and many long-suffering space buffs have conceded that Griffin's Camry approach is the best way to get off the ground on NASA's fixed income.

That doesn't mean it'll be easy to get out of the garage. The transition from shuttle to CEV is fraught with budgetary difficulties. NASA intends to retire the shuttle in 2010, two years before the first orbital CEV mission—a gap that could result in many lost jobs at the space agency. But the shuttle is a voracious consumer of NASA's budget, and every dollar spent on the shuttle is a dollar not spent on the CEV. Already, Congress sees a \$5-billion shortfall in NASA's proposed budget for human-spaceflight programs over the next five years. Unless the White House and Congress pony up more money, that shortfall will mean a delay of several years in the rollout of the CEV.

Even if the CEV does launch on schedule, NASA does not yet have money budgeted for moon missions. Still, the program is under way. The

plans are the most realistic the space agency has ever had for human exploration. Whether our four astronauts get to the moon in 2017 or 2020 is, in the end, a small matter.

PERMANENT PRESENCE

Early in his tenure, Griffin insisted that NASA is the best in the world at some types of engineering. He quickly overrode a previous plan to let aerospace contractors design the CEV. Instead he had his people dictate the basic architecture of the CEV and get to work on critical systems such as the lox-methane rockets, the parachutes and the crew capsule design. For the most part, Lockheed Martin and the Northrop Grumman-Boeing teams are

competing not on innovation but on their track records and the cost-effectiveness of their business plans. (A few matters, however, will be left to them, including whether the CEV capsule touches down by parachutes alone or gets help from a retro-rocket or inflatable bags.)

"This whole program is not going to be about a race, just doing this once," says Doug Young, who leads Northrop Grumman's CEV team. "It's about laying a groundwork for an extended presence in space, on the moon and, ultimately, for missions to Mars." ■

William Speed Weed is a PopSci contributing editor. This is his seventh feature article for the magazine.

FINAL TRIP HOME

The astronauts return to their spacecraft in the lunar lander's ascent stage, which is then jettisoned. The service-module engines fire to send the spacecraft back to Earth. Once in Earth orbit, the crew capsule separates from the service module, reenters, and deploys its parachutes for the final descent to the ground.



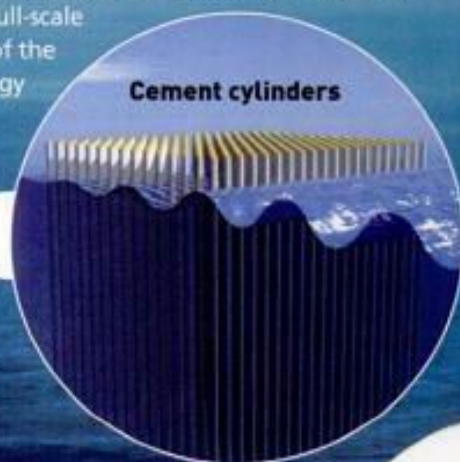


RENEWABLE ENERGY

MAKING BETTER SURF AND CLEANER POWER

A new device that amplifies waves and captures their energy could soon power parts of Rhode Island

BIG OCEAN SWELLS COULD ONE DAY be as exciting to homeowners as they are to surfers, thanks to an innovative new device that harnesses the power of waves to produce cheap, clean electricity. Pioneered by scientists at Energetech, a small alternative-energy company in Randwick, Australia, a prototype of the \$1.5-million device is now in testing off the Australian coast, and Energetech hopes to build another one near Rhode Island by 2007. Moored several miles offshore, Energetech's 40-foot-tall rig relies on the up-and-down motion of waves to force air in and out of a chamber, turning a turbine that produces electricity. The company's president, Tom Engelsman, says that a full-scale unit could power up to 5,000 homes; the output depends on the size and regularity of the swells. But recent theoretical work of two Chinese scientists on amplifying wave energy could soon make devices like Energetech's even more effective. —GREGORY MONE



STEP 1: Enhance Waves

The height of a wave increases as it moves into shallower water—that's why waves get steeper as they approach the sand. According to scientists Xinhua Hu of Iowa State University and Che Ting Chan of the Hong Kong University of Science and Technology, a football-field-size array of solid columns, situated some 300 feet from the rig, could effectively act as a false ocean bottom. The part of the wave that flows through the columns would behave as if it had reached the shallows, doubling in height.

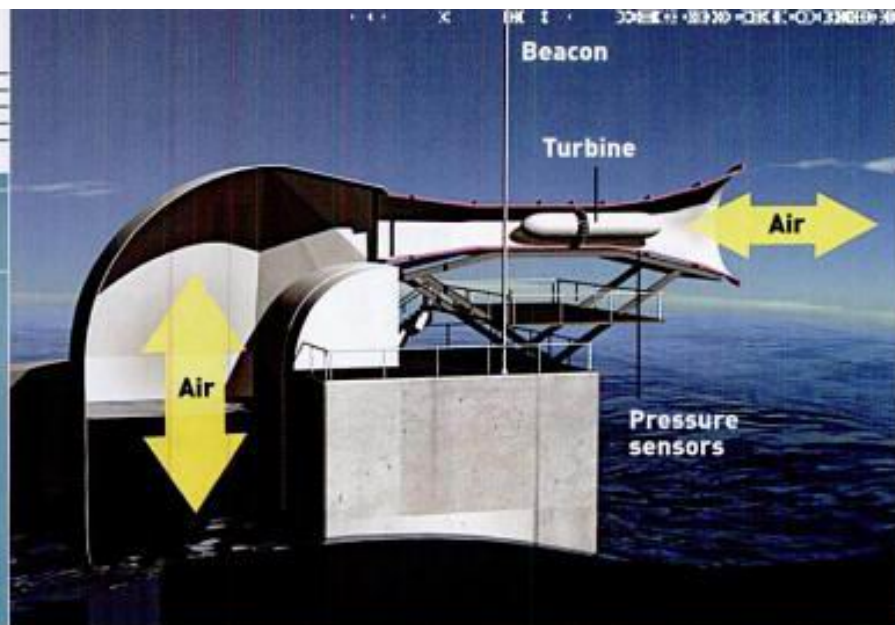
STEP 2: Corral the Swells

The cylinders amplify only the part of the wave headed straight for the converter, so there's no danger to beachgoers. As the wave enters the Energetech converter, the parabolic wall increases its height and further focuses its energy.

STEP 3: Turn the Turbine

When the trough of the wave passes beneath the chamber, air is sucked downward [see diagram, facing page]. Then, as its peak rolls through, air is forced back up, spinning the turbine faster. Bigger waves mean more airflow and, according to Engelsman, "The more air you pump through, the more energy you get."

Parabolic walls

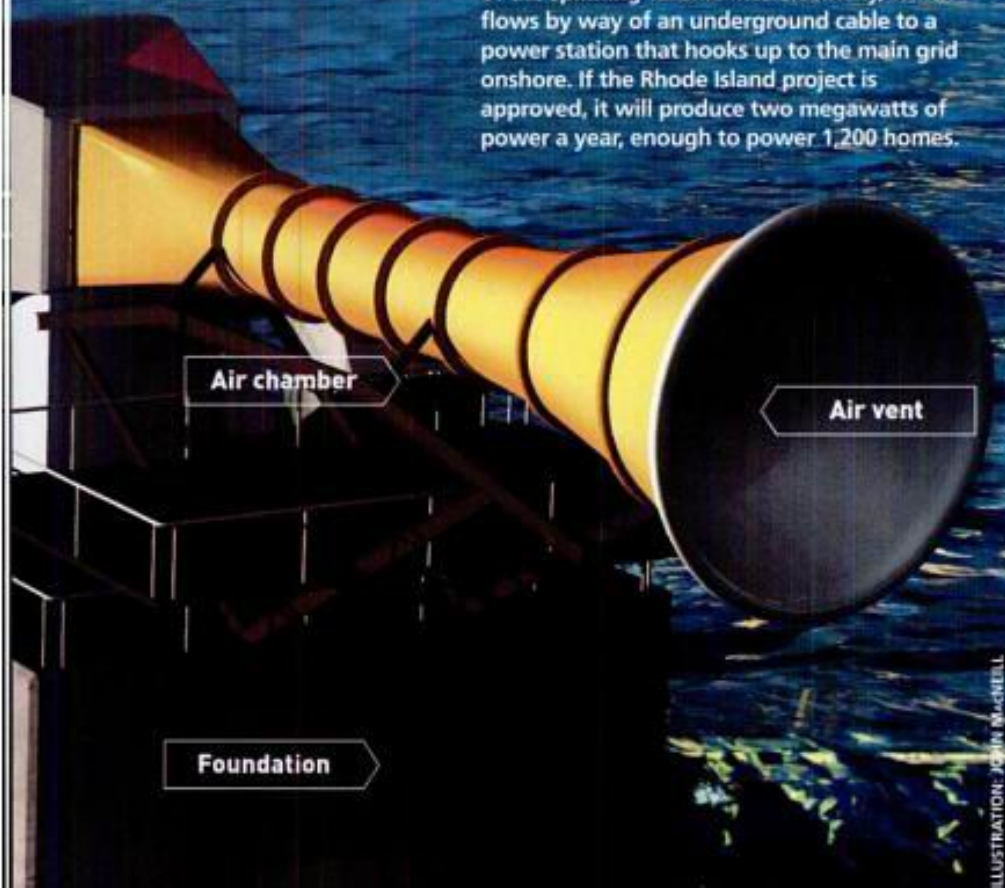


INSIDE THE CONVERTER

The main advance of Energetech's rig over prior airflow-based wave-energy converters is the turbine system. Developed by company founder Tom Denniss, the turbine has rotating blades. Waves flow into the converter, forcing air inside the chamber to spin the turbine. This turbine spins regardless of which way the air is flowing, so there's no wasted energy. Pressure sensors along the chamber wall and inside the nozzle communicate with the turbine, ensuring that the blades rotate to maximize the energy output.

STEP 4: Light up the Mainland

A generator converts the mechanical energy of the spinning turbine into electricity, which flows by way of an underground cable to a power station that hooks up to the main grid onshore. If the Rhode Island project is approved, it will produce two megawatts of power a year, enough to power 1,200 homes.



CONTINUED FROM PAGE 37

requiring us to learn and understand." The biggest challenge in the transition, industry experts agree, will be weaning the companies off lead.

Tin-lead alloy, the industry standard for soldering, is prized for its relatively low melting point of 361°F. The higher melting point in many alternative alloys—63°F higher in the case of the tin-silver-copper mixture that many companies will switch to—creates challenges in the manufacturing process. For one, the increased temperature could damage boards and other components. And a number of the alternative alloys

The U.S. produces two million tons of e-waste every year.

possess poor "wetting," a measure of how well a liquid solder will attach itself to a surface.

Perhaps the biggest unknown in the lead-removal process is the danger of so-called tin whiskers. The subject of much debate and little consensus, tin whiskers are tiny, spontaneous growths that can sprout from surface finishes and cause electrical shorts. In the past, the tin was mixed with lead to prevent the whiskers. The lack of a suitable alternative to lead is one reason the RoHS Directive is loaded with exemptions for industries, such as aviation and the military, that cannot risk potential failure from technologies that have not been proven in the long term.

So what does all this mean for consumers? Most companies say their toxin-free products will look and act the same as their lead-laden counterparts. And despite the fact that the mandate will require RoHS compliance along the entire supply chain, at considerable cost to manufacturers (Intel has reportedly spent \$100 million on the problem), companies insist that prices will remain unchanged.

—BILLY BAKER

The first sign of trouble came when DART mysteriously shut down. At first, NASA ground controllers guessed that it had run out of fuel while it was still a few hundred feet from the satellite. But five days later, an Air Force tracking system spotted the target satellite in a new, higher orbit, making obvious the fact that DART had collided with the satellite. As a test intended to pave the way for new technologies to service orbiting satellites, this was an abject failure. But as an inadvertent demonstration of a basic but potentially devastating space-combat tactic—disabling enemy satellites by ramming them into useless orbits—the mission was a surprising triumph.

Will the Pentagon be carefully studying the DART data? Bet on it. The conquest of space has always served two essential purposes: scientific and technological advancement, and military advantage. It is a poorly held secret that NASA and the U.S. Air Force routinely transfer technologies back and forth between scientific and military programs. As DART demonstrated, virtually every system envisioned by the U.S. to extend our reach in the solar system also has a potential offensive use, from DART's own autonomous rendezvous technology to communications and geographic survey systems that have been evolving for the past four decades. Even the spectacular Apollo lunar landing 36 years ago—executed by Air Force test pilots—was a thinly veiled effort to beat the Soviets to the moon and send a clear message of space superiority. Today, President George W. Bush is every bit as interested as John F. Kennedy was in gaining the upper hand in space. The White House will soon issue a new national security directive that will bring the nation a significant step closer to fielding weapons up there.

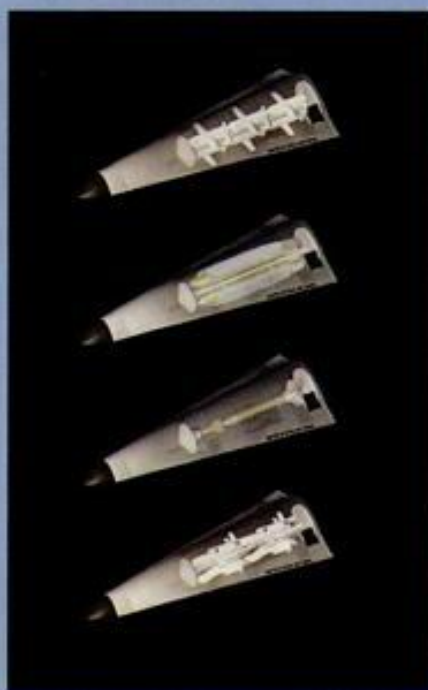
ORBITAL ARSENAL

What those weapons will be will depend on how well the technology develops, but potential future systems include space planes capable of striking targets anywhere in the world in a matter of hours, 20-foot-long satellite-launched "rods from God" that fall from the sky with tremendous force, orbiting mirrors that flash laser beams to distant targets, electromagnetic-pulse weapons that fry satellite electronics, "tugboats" that push satellites into new orbits, satellites that spy on other satellites, and microsatellites that disable or destroy larger satellites.

Among the most pressing demands that space access can alleviate is high-speed, worldwide delivery of weapons. Future hypersonic unmanned space planes will use the advantages of spaceflight to strike anywhere in the world within two hours, a

HYPERSONIC SPACE PLANE

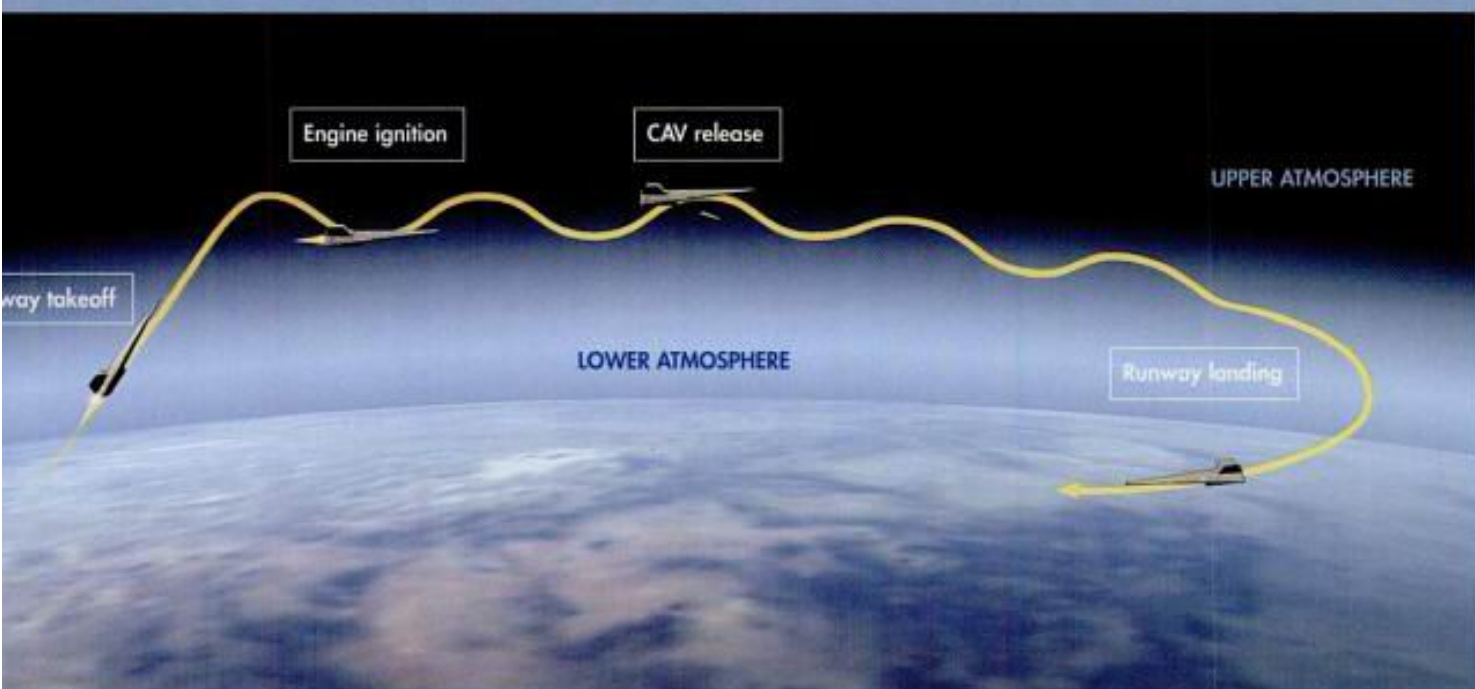
This combo will be able to attack anywhere in the world within two hours: The large hypersonic cruise vehicle releases a smaller, weapons-laden Common Aero Vehicle [right].



SPECIAL DELIVERY

The gliding, self-steering Common Aero Vehicle (CAV) [left] could carry a variety of payloads [top to bottom]: six unmanned aerial vehicles, four smart bombs, one ground penetrator, or six autonomous flying bombs. An unmanned hypersonic cruise vehicle, carrying multiple CAVs, will take off from a runway [right], shut down its scramjet engine when it enters space, and then repeatedly reignite it to create a skipping effect across Earth's upper atmosphere.

PRESIDENT BUSH IS EVERY BIT AS INTERESTED AS KENNEDY WAS IN GAINING THE UPPER HAND IN SPACE.



[ALTERNATIVE ENERGY] CONTINUED

one-megawatt demonstration project in California by early next year. Then, with manufacturing ramped up, Liden wants to get really serious, erecting a 20,000-dish facility somewhere in the Southwest to supply the region with 500 new megawatts, more energy than many nuclear or fossil-fuel plants crank out.

For decades, solar power has been hindered by high costs. Now, however, with coal-fired plants struggling to clean up their emissions, natural-gas plants beset by high fuel prices, and nuclear plants still anathema because of disposal woes, people are reexamining the solar option. The energy source has gotten steadily more affordable, and the U.S. Department of Energy says that solar-dish power could be cost-competitive with conventional sources by 2011.

Dish power could become the go-to stopgap source during periods of high demand.

The concept behind the solar dish dates back to 1816, when Scottish engineer Robert Stirling invented a workable alternative to the explosion-prone steam engines of the day. His version was fueled by wood, not light, and produced mechanical power, not electricity, but his closed-cycle regenerative gas engine is at the heart of the Stirling solar system.

If dish power catches on, it will boost the nation's lagging solar industry, which now generates less than 1 percent of the total power supply. Sandia engineer Chuck Andracka says the dish's modular appeal (you can chain together as many as you want) reduces the amount of start-up capital needed for commercialization. But, he adds, the price per dish needs to fall below \$50,000 to be cost-effective.

Once that happens, dish power could become the go-to stopgap source during periods of high daytime demand, especially during the summer months, when air conditioners strain the power grid. "The U.S. has plenty of baseload power," Andracka says. "It's the peak that we've got to worry about." —JOSHUA TOMPKINS

[SPACE]

Nuking the Sail

A blast of microwave power could give the world's first solar sail a boost

» ON MARCH 1, THE CALIFORNIA-BASED nonprofit Planetary Society will attempt for the third time (or is it the fourth? we've lost count) to launch its privately funded *Cosmos 1* solar sail. A Russian ballistic missile will deliver the 30-meter-wide sail, which is made of Mylar and looks like a giant pinwheel, into an 825-kilometer near-polar orbit. Like a sailboat coasting with the wind, the craft won't need an engine: Pressure from the sun's photons, striking the sail's surface at various angles, will boost its orbital velocity. If the concept is successful, more-developed solar sails might one day cruise among the planets of the inner solar system. And they'll never need to refuel.

To get out of Earth's orbit quickly, however, a solar sail would require more than a gust of sunlight. Physicist and science-fiction author Gregory Benford thinks he has a solution. When the Planetary Society gives them the go-ahead, he and his brother James, the CEO of Microwave Sciences, will use a 70-meter antenna in Goldstone, California, to fire a 500-kilowatt beam of microwave energy at *Cosmos 1*. The influx of high-energy photons will produce at best a tiny change in the sail's velocity—not enough to kick it out of orbit, but enough to measure—and it will stand as an important test. "We know the physics will work," James Benford says. "We're now trying to find the best approach to get us out of the solar system." —PATRICK-DI JUSTO



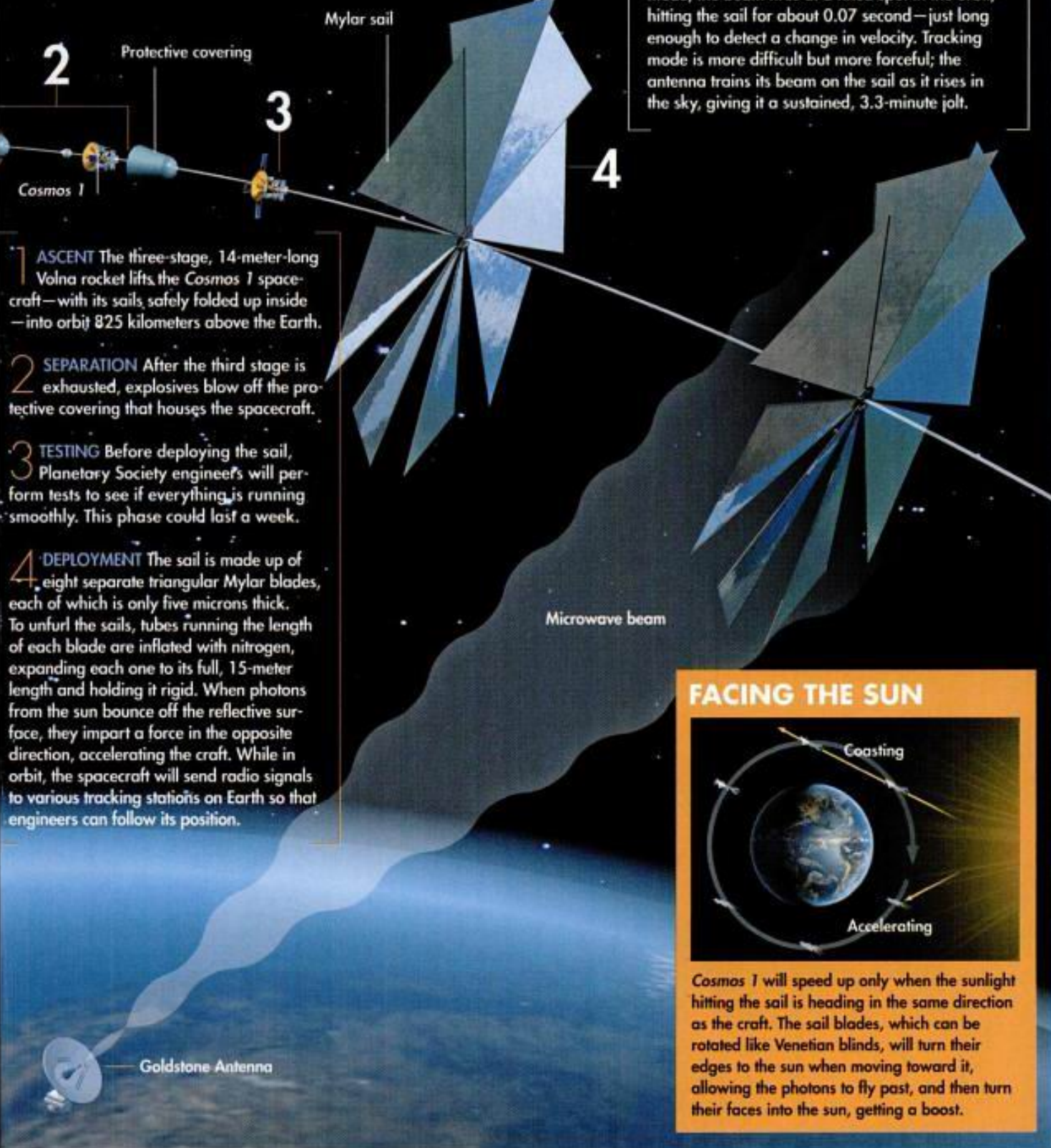
LAUNCH



BLASTING OFF Because the *Cosmos 1* project is privately funded, the Planetary Society had to do some price hunting, and Russia is best for space discounts. A Volna rocket carrying the spacecraft will launch from a submarine in the Barents Sea.

RIDING SUNLIGHT AND MICROWAVES AROUND THE WORLD

★ **MICROWAVE POWER** After two to four weeks of solar sailing, Planetary Society engineers will give the Benford brothers their chance. They hope to test two microwave-beam techniques: impulse and tracking. In impulse mode, the beam fires at a fixed spot in the orbit, hitting the sail for about 0.07 second—just long enough to detect a change in velocity. Tracking mode is more difficult but more forceful; the antenna trains its beam on the sail as it rises in the sky, giving it a sustained, 3.3-minute jolt.



1 ASCENT The three-stage, 14-meter-long Volna rocket lifts the Cosmos 1 spacecraft—with its sails safely folded up inside—into orbit 825 kilometers above the Earth.

2 SEPARATION After the third stage is exhausted, explosives blow off the protective covering that houses the spacecraft.

3 TESTING Before deploying the sail, Planetary Society engineers will perform tests to see if everything is running smoothly. This phase could last a week.

4 DEPLOYMENT The sail is made up of eight separate triangular Mylar blades, each of which is only five microns thick. To unfurl the sails, tubes running the length of each blade are inflated with nitrogen, expanding each one to its full, 15-meter length and holding it rigid. When photons from the sun bounce off the reflective surface, they impart a force in the opposite direction, accelerating the craft. While in orbit, the spacecraft will send radio signals to various tracking stations on Earth so that engineers can follow its position.

FACING THE SUN



Cosmos 1 will speed up only when the sunlight hitting the sail is heading in the same direction as the craft. The sail blades, which can be rotated like Venetian blinds, will turn their edges to the sun when moving toward it, allowing the photons to fly past, and then turn their faces into the sun, getting a boost.

(WE'VE NEVER KNOWN

more about the universe than we do right now—and that's precisely the problem. Every significant astronomical discovery of the past 50 years—afterglow from the big bang, evidence of dark matter, planets circling distant stars, just to name a few—has helped to create an ever-larger and more perplexing set of cosmic questions: Is there life on those faraway planets? How did the first stars form after the big bang? Is the universe filled with an antigravitational force, and, if so, what the heck is it? And most intriguingly: What else are we missing?

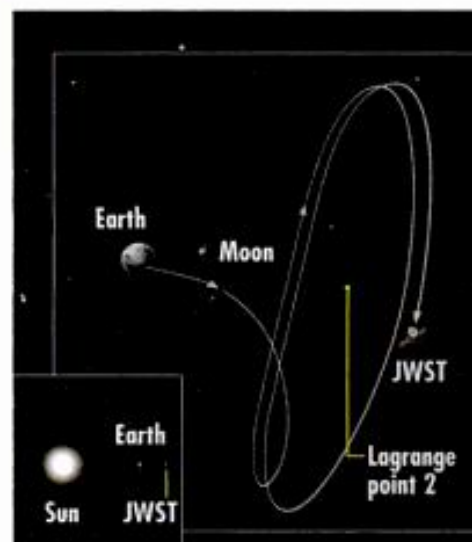
Answers to questions like these do not come from idle reflection. They come from building really good telescopes. Over the next decade, the first generation of telescopes conceived, designed, and built with the help of computers will open their eyes to the heavens, each with the power to rock our fundamental understanding of the cosmos. Some of these telescopes—such as the trio of satellites riding gravitational waves on the preceding pages—don't look like traditional telescopes at all, but each has the ability to reach out into the universe and uncover its idiosyncrasies, its wonderful strangeness.

On the following pages we profile 10 of the most important, audacious and powerful of these instruments, including a space telescope so large it must be folded to fit in the rocket, an orbiting laser system that can detect ripples in spacetime from colliding black holes, and an Antarctic neutrino detector that uses the mass of the Earth as a protective shield. What secrets of the universe will they reveal in the coming decades? The answer to that question may provide the greatest mystery of all.

(1)

● JAMES WEBB SPACE TELESCOPE UNDISPUTED KING OF THE NIGHT SKY

- SPONSOR } NASA, Space Telescope Science Institute
- LOCATION } In orbit, one million miles from Earth
- COST } \$2.5 billion
- SCHEDULED COMPLETION } 2011
- URL } jwst.nasa.gov



FAR-OUT To protect JWST's sensitive infrared detectors from Earth's heat, researchers will orbit it around Lagrange point 2—four times as far from Earth as the moon.

TELESCOPE ORIGAMI

JWST's primary mirror is far too large to fit in any existing rockets, so engineers designed it from 18 hexagonal segments mounted on two large hinges. The folded mirror will squeeze into an Ariane rocket fairing [1], and will unfurl once in orbit [2-4]; 126 motorized actuators will then adjust the segments into focus, 10 nanometers at a time.

IN AUGUST 2011, MOST LIKELY atop an Ariane rocket rising from a launchpad in French Guyana, a 6.5-meter beryllium-and-gold mirror will sit folded into thirds like an elegant drop-leaf table, enduring the hellish forces of liftoff. The James Webb Space Telescope's primary mirror is as big as a two-car garage, and there isn't a roomy enough rocket fairing to carry it unfolded.

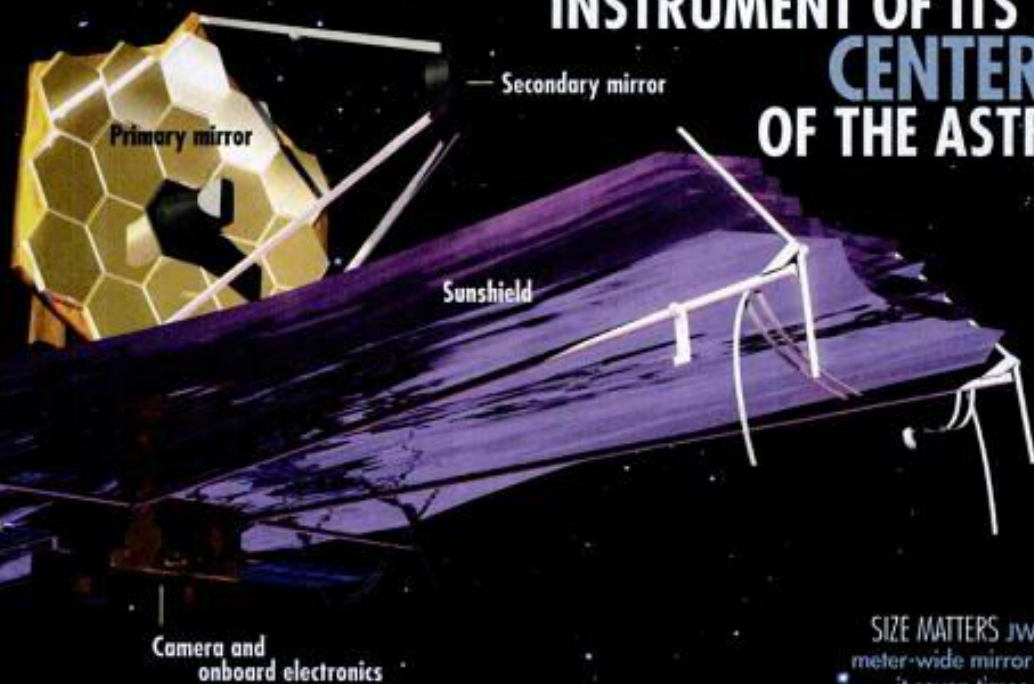
Once in space, the biggest telescope ever launched will unfold its mirror and unfurl a 2,400-square-foot sunshade as it drifts into orbit around Lagrange point 2, a spot one million miles away from Earth where net gravitational forces are very weak. Why place it so far away, out of reach of any repair or upgrade mission? Because out there, the infrared telescope won't feel Earth's heat. The JWST, you see, will be looking out at the cosmos with an infrared camera, somewhat like the night-

scopes that soldiers use to spot enemies in the dark, but incomparably more sensitive. (JWST project scientist John Mather calls his detectors "miraculously good" and "nearly perfect.") Any heat near the telescope will show up as noise—hence the million-miles-from-Earth orbit, sunshade, and onboard cryogenics that will cool the optics down to just 37 Celsius degrees above absolute zero (-393°F). The telescope, says Mather proudly, will be so sensitive in the infrared that it will find stars and galaxies that send out only a few photons per hour.

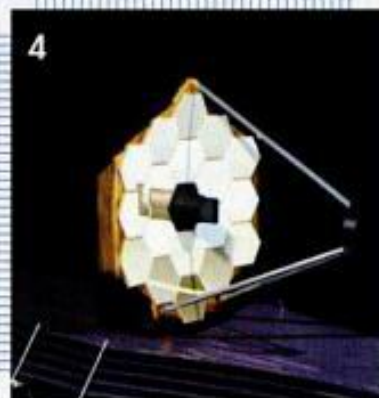
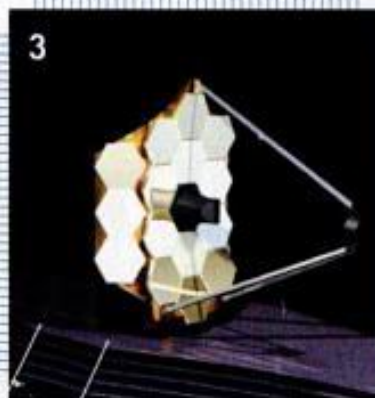
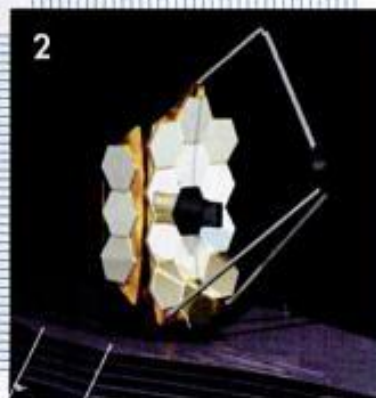
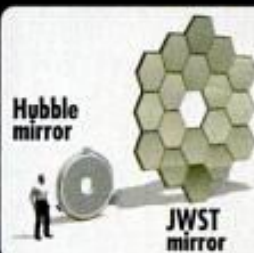
What stars and galaxies might be so stingy with their infrared photons? Ones that are extraordinarily far away in space and time. And that's the big headline. Ever since Edwin Hubble proved in 1929 that galaxies are flying away from one another, the telescope race has been about peering deeper into space in order to see further back in time. Because it's so big, and so cold, and so sensitive, Mather says, JWST should be able to find "the first luminous objects that formed after the big bang." If JWST accomplishes its goal, we'll have reached, in a sense, the end of the line. No telescope of the future will help us see stars more distant in space or time, because there aren't any.

Before it was named after NASA's second administrator, the JWST was called the Next Generation Space Telescope, and mission planners don't take that appellation lightly. Thanks to increased computing power, improved materials and precision tooling, the technologies available to them today are simply incredible—among them, detectors that sense a single photon that's traveled billions of light-years and a mirror that can correct its shape just 10 nanometers at a time using 126 motorized actuators. JWST's mirror is being sculpted of beryllium, a very hard metal that's notoriously difficult to machine, but it's so light that the 6.5-meter mirror will be one third the weight of the 2.4-meter

IT WILL BE THE PREMIER INSTRUMENT OF ITS AGE, THE CENTER POLE OF THE ASTRONOMY TENT.



SIZE MATTERS JWST's 6.5-meter-wide mirror will give it seven times the light-collecting power of Hubble.



**IT STANDS A GOOD
CHANCE OF BEING THE
FIRST TELESCOPE TO
IMAGE A PLANET
AROUND ANOTHER STAR.**

Secondary mirror

Telescope enclosure

AUTO-FOCUS Computer-controlled pistons will continuously adjust the alignment of each of the 1,000 segments that make up the TMT's primary mirror. This adaptive optics system will correct for distortions caused by the turbulent atmosphere.

(2

Tertiary mirror

Primary mirror

glass mirror on the Hubble—the most important telescope ever created. It will be covered in a single-micron coating of pure gold, an excellent reflector of infrared light. “Twenty-five years ago,” Mather explains, “we were designing with what seemed like the dark ages of tools, and we had to guess a lot on Hubble. Hubble was designed for the shuttle to repair it. Now we can analyze and plan for everything ahead of time.” Although JWST, at about \$2.5 billion, is the most expensive item on this list, such dramatic improvements are typical of the whole cohort of new telescopes.

Like the Hubble, the JWST is available to every astronomer with a good idea. In addition to capturing the earliest objects, JWST will image regions where baby solar systems are forming, seek out evidence of dark matter and dark energy, and snap amazing pictures of Neptune and Uranus. It will be the premier instrument of its age, the center pole of the astronomy tent. Astronomers have one clear expectation for it: “It’s going to surprise us,” Mather says. “One half to two thirds of what we got out of Hubble was not what we expected. We’ll find something that will not be what we predicted about the universe,” raising new questions for the next next generation of telescopes to solve.

THIRTY METER TELESCOPE A GIANT SCRUTINIZING THE BIRTH OF THE UNIVERSE

- SPONSOR) Research-university consortium
- LOCATION) On Earth, place to be determined
- COST) \$700 million (est.)
- SCHEDULED COMPLETION) 2014
- URL) astro.caltech.edu/observatories/tmt

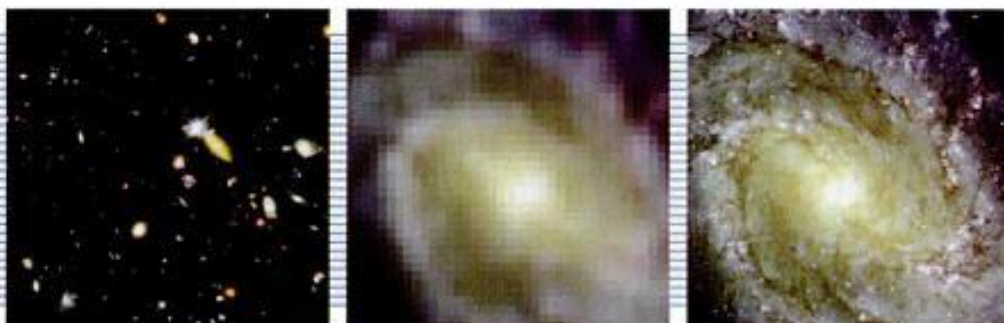
AN 18-HEXAGON MIRROR the size of a garage? Ho-hum. Freed from the requirements of rockets and of space travel, the next giant ground-based telescope will have a primary mirror the size of a 20-lane bowling alley. Put it on its edge and the proposed Thirty Meter Telescope will stand as tall as a seven-story

building. Fill it with water and you’ve got a pool big enough for 50 kids to swim in.

The research-university consortium that’s designing the TMT won’t be filling it with water, of course, but with light—more light than astronomers have ever collected in one mirror. This telescope will have more light-collecting power than the 10 largest telescopes in the world today combined. The designers hope to build it, says TMT project manager Gary Sanders, “in the JWST time frame,” meaning about a decade.

John Mather of JWST is very eager that both projects succeed, because the orbiting Hubble and the Keck telescopes atop Mauna Kea in Hawaii proved that ground- and space-based telescopes are complementary. What they can do together outruns the sum of their individual contributions. In the darkness of space where contrast between black void and starlight is strongest, a telescope like JWST can find very faint objects that no one has ever seen before. Once the JWST locates one of these objects, the TMT will train its giant eye on it for hours, creating a sharper image and testing to see what it’s made of.

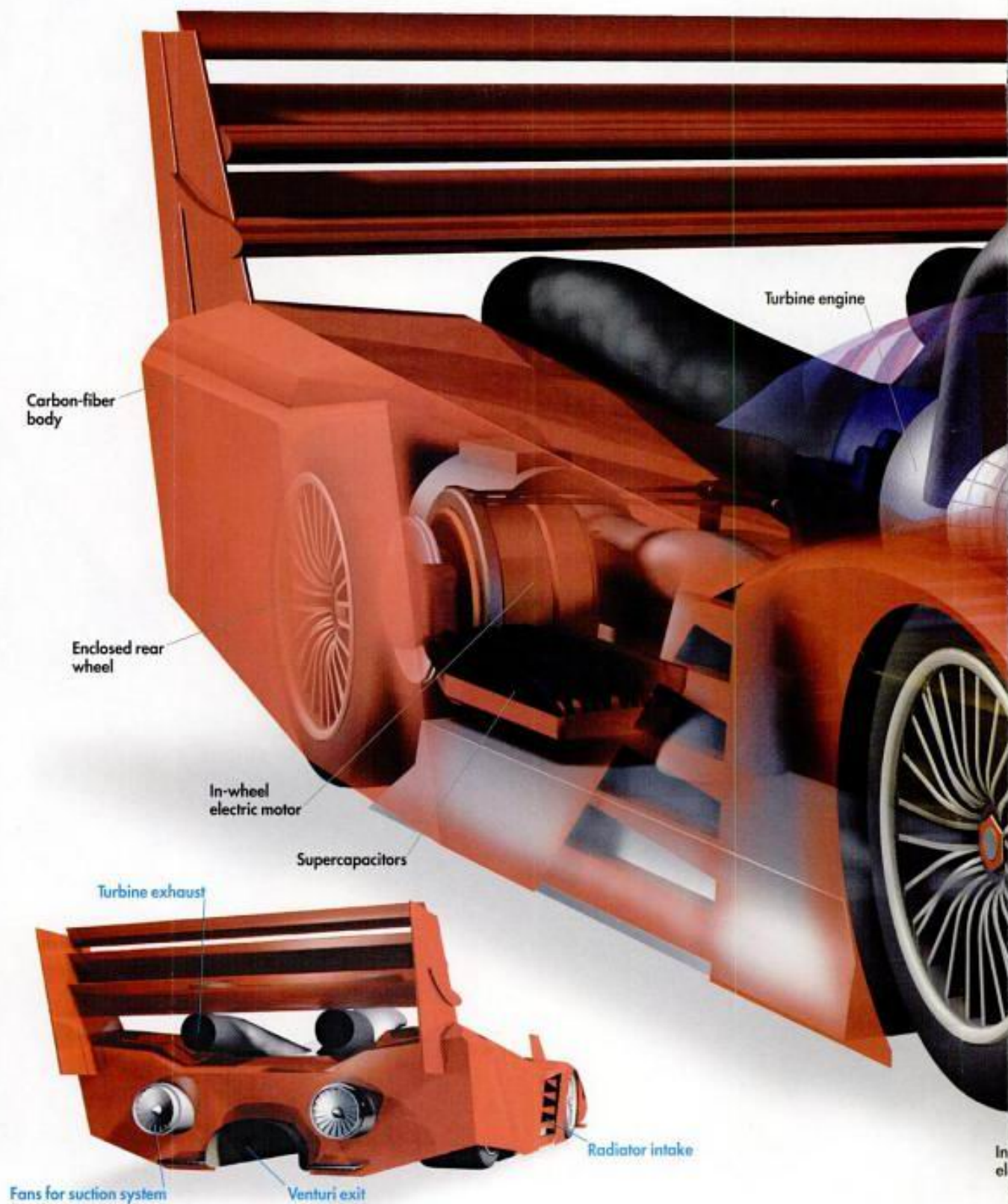
The process is not unlike a biologist going out into the field to grab an interesting specimen and then taking it back to the lab for detailed study with a microscope. Here, our specimens are the first stars in the universe, and our microscope—the TMT—should reveal how these stars created heavier elements such as carbon and iron in their fusing nuclear cores. Astronomers will use a process called spectroscopy to track the formation of these elements as the universe aged. The TMT will separate light from the earliest stars into its various wave-



THE SHARPEST EYE The Hubble captures amazing images of the distant universe [left], but individual objects can be pixelated and blurry [center]. In contrast, the TMT’s shots of the same objects will be astonishingly sharper, as seen in this simulated image [right].

ANARCHY on the Raceway

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exists today, at l

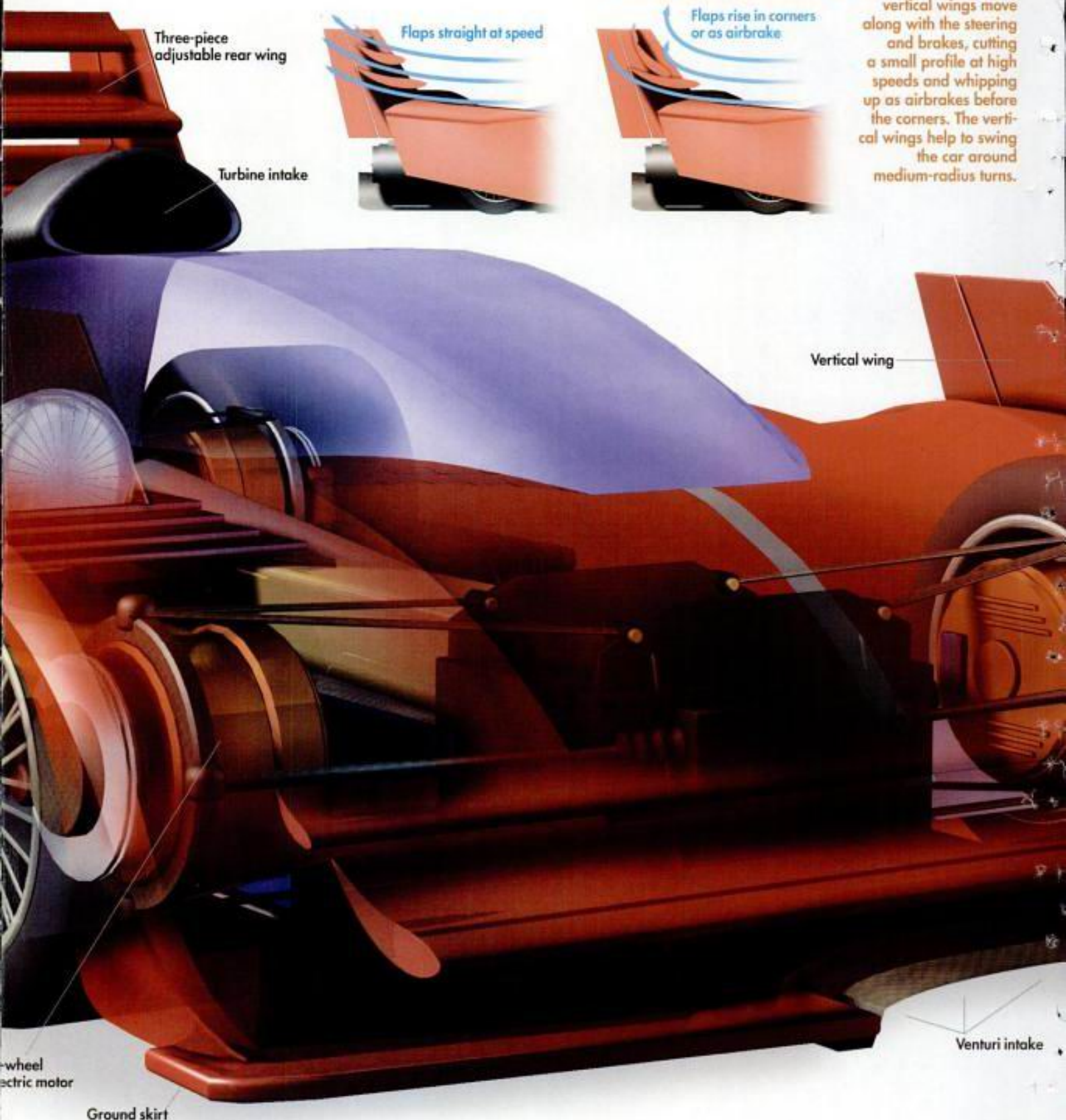


...less, we at PopSci decided to take the wild racecar in "Formula None" (page 120) a few steps further. The based on a Le Mans racer, but the extensive modifications age in concept cars and jet fighters. All the technology fast in the laboratory.

WINGTIP TO WINGTIP

Today's racecars must find a balance between downforce and drag: Too much of the first in the corners leads to the second in the straights. One way to overcome these compromises is through instantly adjustable aerodynamics. Flaps on the spoilers and vertical wings move

along with the steering and brakes, cutting a small profile at high speeds and whipping up as airbrakes before the corners. The vertical wings help to swing the car around medium-radius turns.



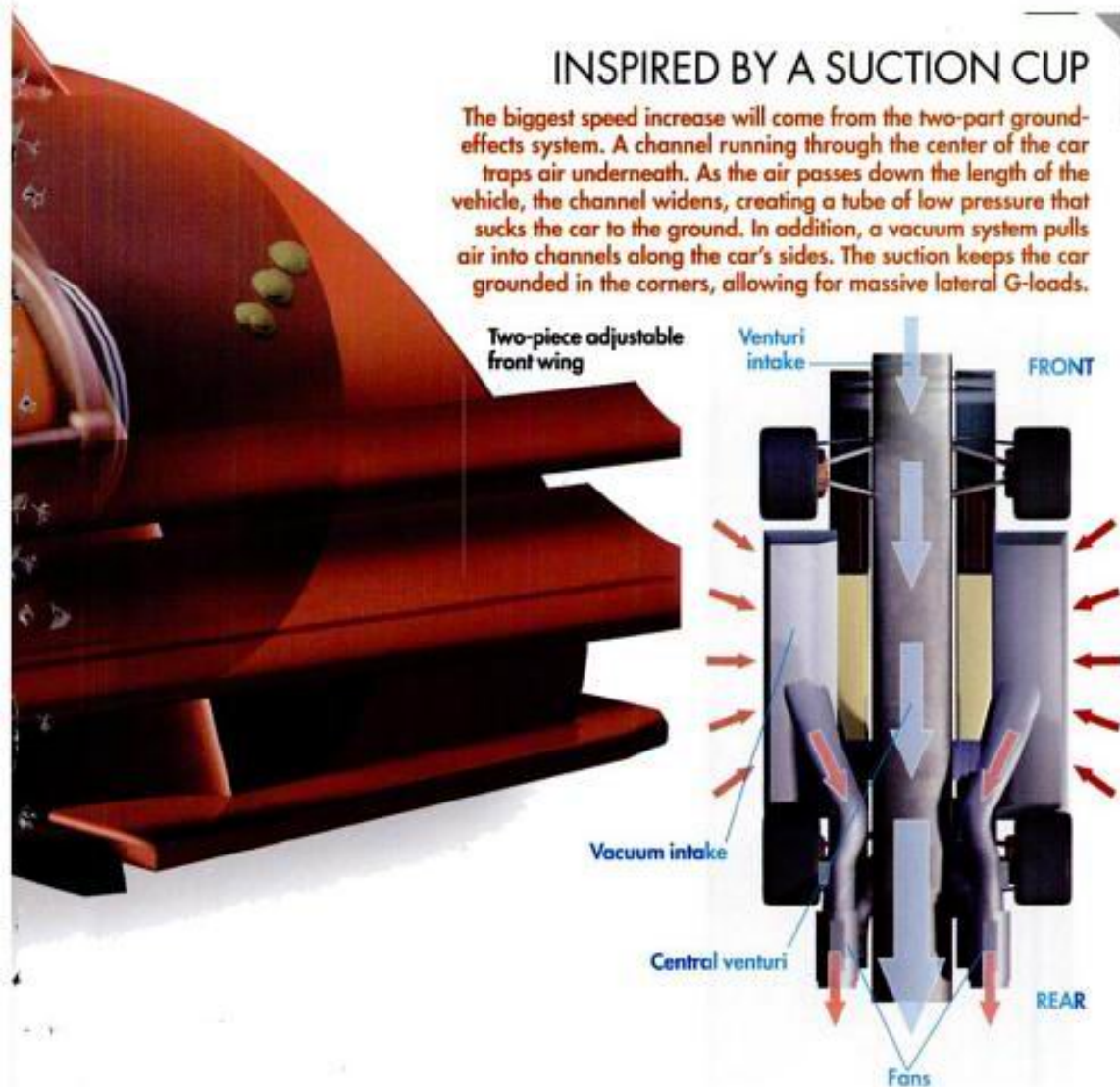
THE MOTHER OF ALL HYBRIDS

Turbines, with their tremendous power-to-weight ratios, seem perfect for racing. They aren't nearly as responsive as piston engines, though, which has helped keep them off the track. To overcome this, we've created a hybrid turbine-electric powertrain. The turbine runs continuously, but its driveshaft is connected to an electric generator instead of directly to the axles. The generator powers four in-wheel electric motors and keeps a supercapacitor fully charged for an extra boost when necessary. The supercapacitor stores energy like a battery yet discharges it much more quickly.



INSPIRED BY A SUCTION CUP

The biggest speed increase will come from the two-part ground-effects system. A channel running through the center of the car traps air underneath. As the air passes down the length of the vehicle, the channel widens, creating a tube of low pressure that sucks the car to the ground. In addition, a vacuum system pulls air into channels along the car's sides. The suction keeps the car grounded in the corners, allowing for massive lateral G-loads.



THE TRA

1. Upside-down section
2. Grates through chicanes
3. Narrow corner
4. Start and finish lines
5. Outward-banked turn

OUTSIDE TUR

Another strategy racetrack designers might use is to simply make the track exceptionally difficult—by means of sharper turns, shorter straights or, creatively, banking turns to the outside so that the racers' centripetal force works against them. Such turns would put a higher premium on a light-weight chassis than on tire grip.

CK TO TAME IT

● If there are no rules on the track, the track must *become* the rules. This design, based on the Road Atlanta raceway, suggests how a future race-track might be modified to constrain and challenge the cars. Narrow turns limit vehicle size; grates in the asphalt mitigate ground effects; and reverse-banked corners regulate speed. The downforce of the racecars will be so strong that we included an upside-down section, just for fun.

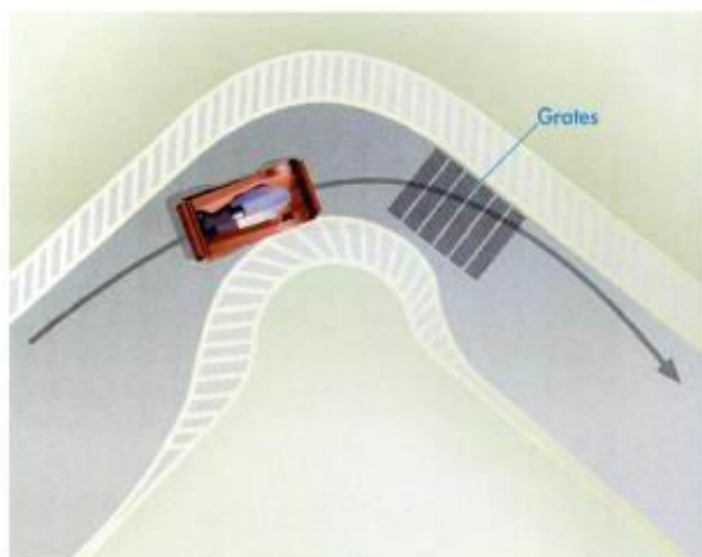
OVER THE TOP

At speed, these racers will generate around 20 times their weight in aerodynamic downforce. The most obvious way to demonstrate this grip is to twist a section of the track until the cars are upside down (think geckos on the ceiling). Dangerous, yes, but the loop could actually prove to be a relief for drivers: After multiple high-G banked turns, inversion would pull the blood back into their heads.

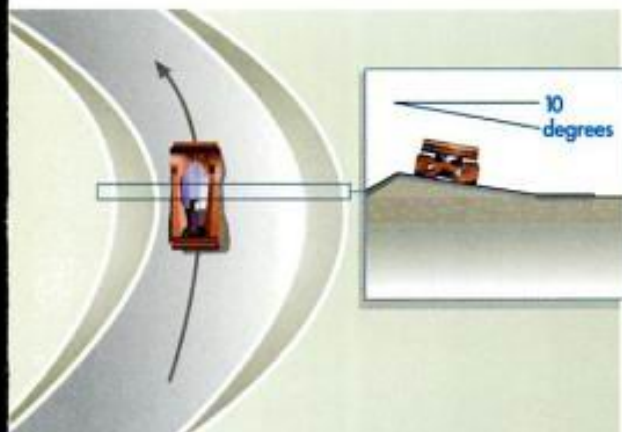


CORNER GIRDLE

Unconstrained racecar designers might be tempted to vary the dimensions of the car, lengthening it for stability at speed, widening it simply to make it more difficult to pass. By including at least one exceptionally narrow corner, the track designers would effectively restrict cars' dimensions. In addition, ventilated grates in the turns could nullify suction or venturi systems, reducing downforce and, consequently, cornering speeds.



NING IN



alluded to a second-generation vehicle that would tote more tourists.

"It makes an enormous difference to fly 6 to 10 people," he noted. *SpaceShipOne* incorporates a scalable design that could balloon in size without necessitating significant changes to its shape. Such a craft would not only be larger but would fly higher than *SpaceShipOne*, to give more "time to unstrap and float around," Rutan says. Frank Macklin, an engineer at SpaceDev, a company that built components for *SpaceShipOne*'s hybrid rocket, says it's

ORBITAL SPACE TRAVEL IS A "BIG, BIG STEP," CAUTIONS AEROSPACE EXPERT PAUL CZYSZ. "IT TAKES 70 TIMES AS MUCH ENERGY TO GET UP—THE CURRENT DESIGN WOULD NEVER MAKE IT."

feasible to build a rocket motor large enough to power a suborbital bus.

But Rutan wants to offer customers more than just zero-G floating. "I don't think orbital travel makes sense if you stay in the spacecraft—you have to go to a resort hotel in orbit," he said in June. Reaching the speeds needed for orbit would require building a small, cheap and cramped transfer van rather than a roomy tour bus.

That task won't be as easy as scaling up and strapping on a bigger motor. Paul Czynsz, an aerospace engineer at St. Louis University, points out that going higher means going faster, and more speed equals more heat. Orbital space travel is a "big, big, step," he cautions. "It takes 70 times as much energy to get up, and the current design would never make it in one piece." In addition to pricey thermal protection, an orbital van would also need a fully automatic control system for stability in space, and a multistage rocket booster.

Nobody, least of all Rutan, is talking about how much time and money these craft would take to develop. "Sometimes he's brilliant," Czynsz says. "But sometimes there are practical things that turn round to bite him." —BILL SWEETMAN

ADVENTURES IN AVIATION

ORBITAL THRILLS

So you want to be a space tourist? Buckle up.

What does it feel like to rocket 62 miles above Earth? Realistically speaking, most of us will never know. So we asked Mike Melvill, test pilot for *SpaceShipOne* and the first guy to hang out in suborbit without government support, to tell us about his historic trip in June. The experience followed the emotional trajectory typical of any serious amusement-park ride: boredom, gut-wrenching fear, awe, more gut-wrenching fear and, finally, relief. Still want to spend your life savings on a joyride to space? Tickets to board a Rutan-designed commercial spaceship could go on sale as soon as 2010.

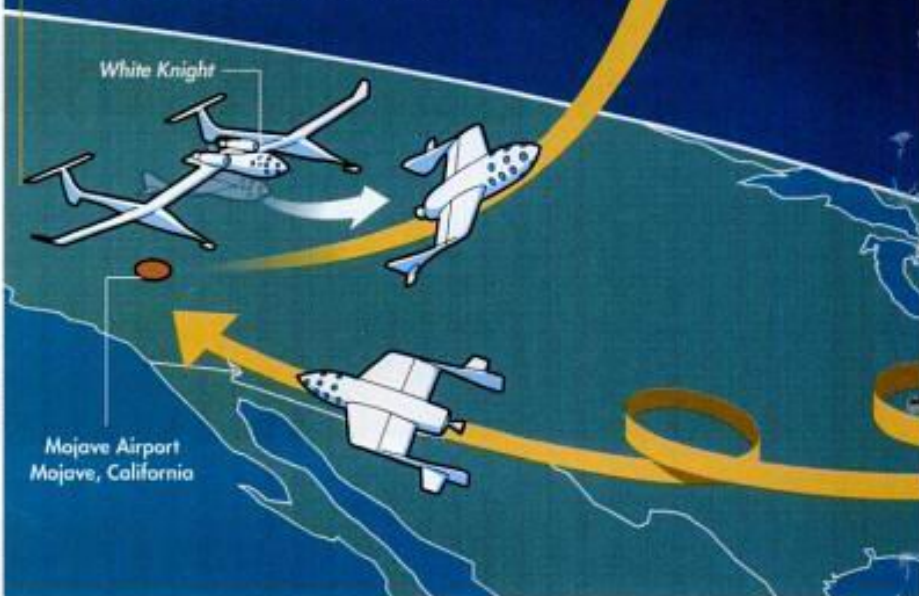
1 TAKEOFF AND ASCENT

Mojave Airport, 6:47 a.m.: Carrier craft *White Knight* totes *SpaceShipOne* up to 50,000 feet.

Melvill: "There's little for me to do, so it's a pretty lonely time. At 43,000 to 44,000 feet, we start going through the checklist. We make sure that the cabin is properly pressurized and that the specific trim settings are ready."

2 SEPARATION

7:50 a.m.: *SpaceShipOne* detaches from the mothership, Melvill fires its hybrid rocket motor, and the craft climbs skyward. "The motor lights flick on and I get three horizontal G's, followed by four vertical G's. It's very disorientating. You feel like you're falling on your back. You're near Mach 3, faster than an M-16 rifle bullet, and you feel like if you do anything wrong, you might really hurt yourself. Even if a good pilot got in that thing, without training he'd be dead when he lit the rocket."



3 HANGTIME

7:52 a.m.: Near the top of the boost stage, Melvill runs into serious trouble when a trim motor fails. "I lit the motor, and the spaceship rolled 90 degrees to the left by itself. I stomped on the pedal to correct the motion, and then it went 90 degrees right. I really thought it was all over, but luckily I popped out of the atmosphere. After that, I took out some M&Ms and just let them float in front of my face. I could see the curvature of Earth, and the low clouds over Los Angeles looked exactly like snow on the ground."

Suborbital space

TAKE IT HIGHER?

SpaceShipOne's Mach 2.9 maximum speed may seem fast, but the craft will need to hit Mach 25, or 17,500 miles an hour, to reach orbit. The extra push will require a more powerful fuel system than the one that now boosts SpaceShipOne. And keeping the ship from incinerating during reentry will require a pricey heat-resistant shell.



SPACE STATION
400 km

ORBITAL VAN
360 km

SUBORBITAL TOUR BUS
145 km

SPACESHIPONE
100 km

747
10 km

4 REENTRY AND LANDING

7:57 to 8:15 a.m.: With the plane's wings feathered upward for stability, Melvill drops down to 61,000 feet and then glides it into a smooth horizontal landing. "I was afraid on the way down. The noises are different. The breeze going by at Mach 2.9—3,100 feet per second—sounds like a roaring hurricane. I was holding the controls centered and hoping that the damn thing wouldn't fall apart. I was so glad to set down without breaking anything."

What's New

GENTLEMEN, START YOUR DROOLING

REINVENTING TIME FOR THE WELL-HEELED MOTORHEAD.

▶ Tag Heuer has always ruled the racetrack—from its Carrera chronograph in the 1960s to last year's SLR, designed to resemble the Mercedes-Benz supercar of the same name. But never before has the Swiss watchmaker gone so far as with the Monaco V4, which reaches under the hood to take inspiration—both aesthetic and technological—from the internal combustion engine. Unveiled as a prototype this past April in Basel and not yet scheduled for release, the V4 is the first wristwatch ever to run on drive belts.

Automatic watches ordinarily use dozens of gears to power movement, but belts are more efficient because they cut out the friction inherent in a chain of cogs.

The V4, which took 20 months to develop, uses 13 half-millimeter-wide synthetic belts. They drive metal wheels that rotate on low-friction microball races rather than the synthetic

FRONT



TAG, YOU'RE IT: The first watch to use drive belts to power movement.

BACK



WATCH THE REVOLUTION: Three panels of synthetic sapphire provide a peek under the hood of this chronometer.

ruby pivots known as jewels. The movement is powered by a platinum ingot that shuttles back and forth to turn a cog as you move your wrist. The drive belts transfer that torque to four spring-loaded barrels, which run a balance wheel (more belts) that ticks off the hours, minutes and seconds indicated by the watch's hands.

While none of these changes are exactly necessary, the V4 falls into a long and illustrious line of watchmaking innovation, otherwise known as showing off. Critics point out that a weight limited to moving along one axis can capture only a fraction of the energy that one free to pivot 360 degrees can. What they're ignoring is the watch's aesthetic—and the audacity of its design. The V4 won't set watchmaking on its head in the way ultra-accurate, low-cost quartz movements did in the early 1970s, but it may be the biggest innovation since then. Either way, it'll cost you between \$6,000 and \$12,000. —JONATHAN KEATS

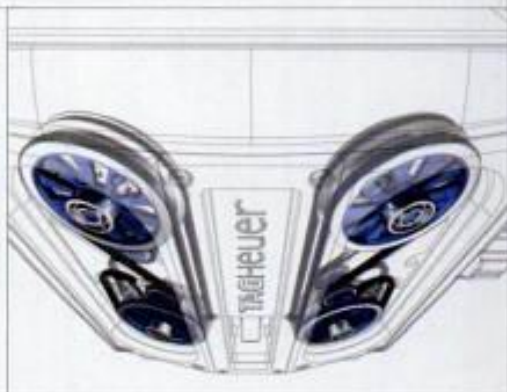


THE ENGINE

A 4.25-gram platinum ingot slides back and forth in a central channel at the back of the watch, capturing power from the wearer's wrist movements. The ingot is machined with teeth along one edge that engage a cog at the side of the channel, rotating it with each pass.

THE TRANSMISSION

Four synchronized barrels, each containing a metal spring, store enough energy to run the V4 for 50 hours even when you're not wearing it. The barrels turn the movement using 13 0.5mm-wide belts tightened with minuscule turnbuckles to a tension far beyond what jeweled pinions could sustain.



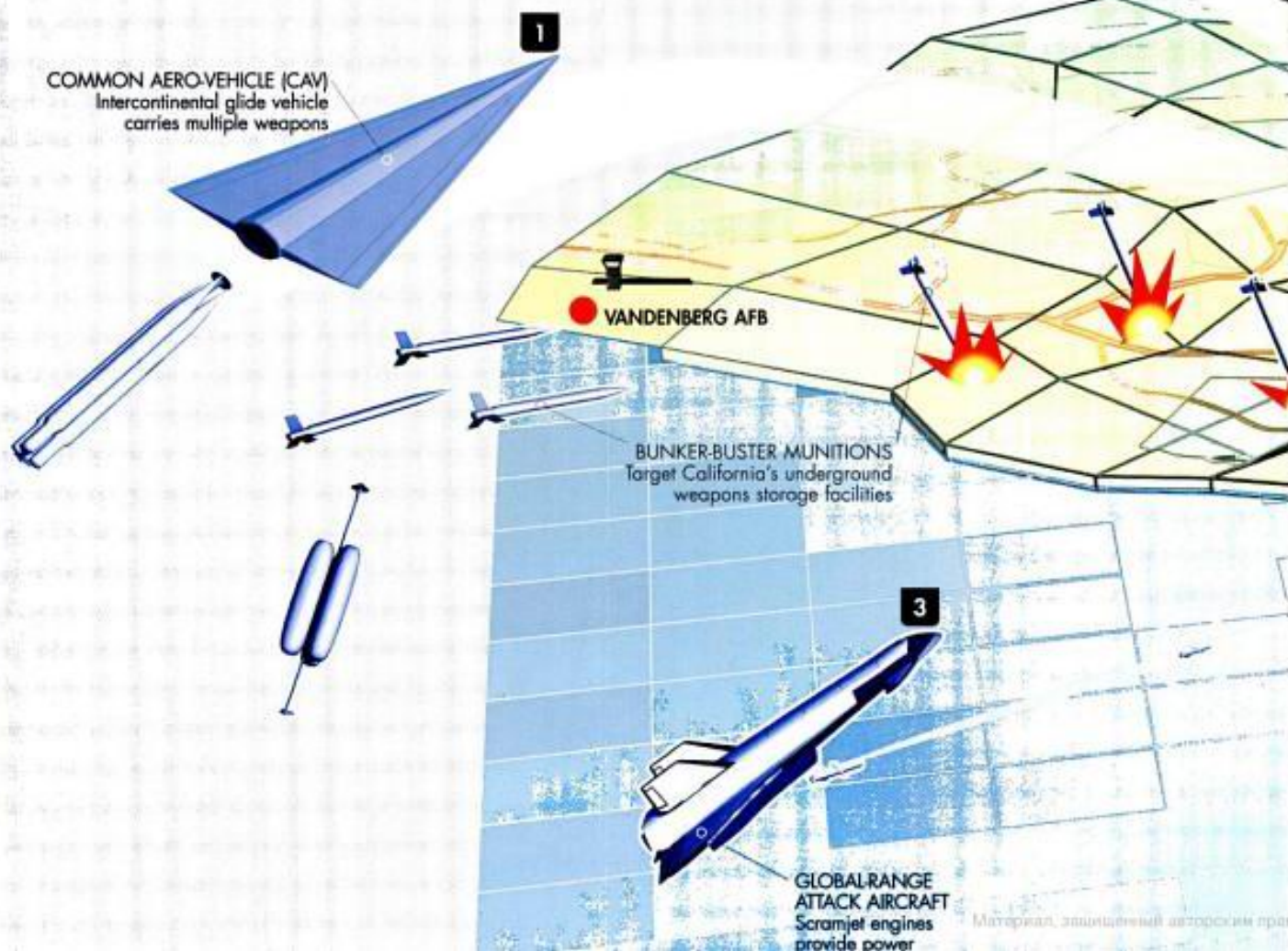


July 4, 2043

AFTER 10 YEARS OF federal tax fiddling during the worst economic depression in 100 years, residents of the western United States are mad. A classic California initiative, nicknamed Proposition Angry Bear, gains momentum: Voters will decide whether to secede. On VN—VirtualNet, the holographic Wi-Fi successor to television—the pending vote is spun by FoxCNNPBSMSNBC analysts as West Coast bluster, until a 72 percent “yes” count, concentrated in the Los Angeles SuperSrawl, makes things ugly. L.A.-based National Guard troops seize key industrial facilities and military bases with the assistance of a small cadre of local U.S. troops sympathetic to the secessionist cause. The bases contain high-tech matériel and combat resources, including the latest beam weapons, hypersonic scramjet cruise missiles, daytime stealth fighters, and surveillance and attack UAVs. The “SoCal” rebel forces announce they’ll deploy no weapons of any kind unless fired upon. The president calls for everyone involved to surrender within 12 hours. When the deadline passes with no surrender, the commander in chief orders the U.S. military to reestablish control of the SuperSrawl, an urban landscape populated by more than 17 million people, with minimal casualties. Although no one expects SoCal forces to use their mini-nukes or other WFDs (weapons of focused destruction), the president resolves to destroy California-based hardware as soon as possible. Meanwhile, destabilizing operations supporting the insurrection—viral avatars, virtual-mail messages to neural implants—radiate from graybeard anarchist hackers in the Bay Area.

[KEY]

- FEDERAL AIRPOWER
- CALIFORNIA AIRPOWER
- LOCAL AIRPORT



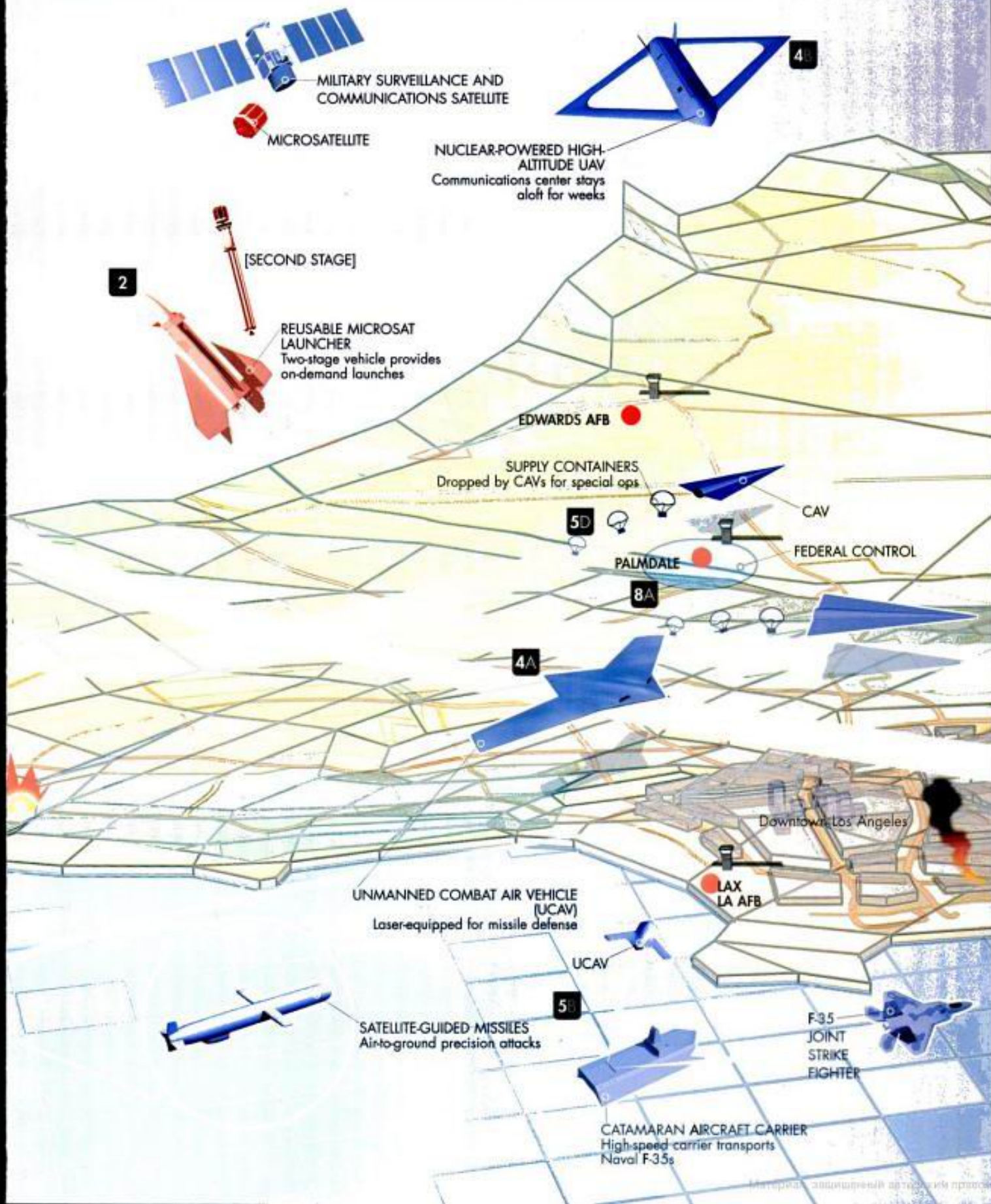
1. [T+30 MINUTES]

Quick-launch **Common Aero-Vehicle (CAV)** weapons delivery systems arrive first. The CAVs travel at Mach 10 and can

hold a variety of weapons. Some carry precision-guided **bunker-buster munitions** aimed at weapons facilities. Others decelerate to subsonic

speed and, above the San Bernardino Mountains and the Mojave Desert, release fuel-cell-powered loitering weapons to search for mobile

missile launchers. Some weapons are aimed directly at communications facilities located at the crests of the Angeles mountains.



2. T+2 hours

Using stolen federal launch codes, SoCal employs reusable **microsatellite launchers** to send its **microsatellites** to attack key

U.S. military surveillance and communications satellites. Within hours, the U.S. replaces its lost satellites using launchers of its own.

3. T+6 hours

The first hypersonic **global-range attack aircraft** appear over Los Angeles and San Diego, and also over Camp Pendleton Marine Corps Base and Vandenberg Air Force Base, releasing **satellite-guided missiles**. Their targets are heavily protected objectives

such as air defense and command centers; they attack with precision-guided 2,000-pound weapons, with the goal of disrupting defenses before other aircraft move in.

4. T+12 hours

(A) Long-range **unmanned combat air vehicles (UCAVs)**

E10-A MULTISENSOR COMMAND AND CONTROL AIRCRAFT
Airborne command post

5A

F/A-22 RAPTOR
Laser-armed air-to-air fighter

PELICAN TRANSPORT
Carries up to six million pounds of cargo

6

29 PALMS

5C

F/A-22 RAPTOR
California's airborne defense system

PALM SPRINGS

F-35 JOINT STRIKE FIGHTER
Multi-purpose fighter

8B

EL TORO

FEDERAL CONTROL

CAMP PENDLETON
MARINE CORPS BASE

SEAL BEACH
NAVAL WEAPONS
STATION

7 The Urban Front

D

armed with anti-missile lasers begin air campaign. Invisible because of stealth technology, they begin 24-hour surveillance and shoot down SoCal missiles aimed at attacking fighters.

(B) The U.S. commits its scarcest air assets—**nuclear-powered high-altitude unmanned aerial vehicles (UAVs)** carrying high-power radar, lasers and communications equipment. These will remain on constant patrol, using powerful transmitters to beam misinformation into SoCal's information systems.

Some California citizens load vehicles and try to head out of town, but the precision of the attacks—combined with

propaganda subtly beamed onto the VN—convinces many to stay home. Rather like the residents of Washington, D.C., during the first part of the Civil War who brought picnics to watch the first battle of Manassas, some Californians watch incoming strikes from the beach.

The first cruise-missile-carrier aircraft move into position, a safe distance from California airspace. Moving targets spotted by drones can now be engaged within 10 minutes by hypersonic cruise missiles. Stealthy subsonic missiles fed refined targeting information inflight can hit a fixed target within inches of the aim point.

7E7 DREAMLINER
Modified to serve as Air Force One

9



- A** LAMV TRANSPORT
Unmanned supply craft
- B** ARMORED VEHICLES
Lightweight artillery
- C** MINI-UAV
Ground-troop support
- D** A160 HUMMINGBIRD
Helicopter-like UAV
- E** MICRO-UAV
Interior surveillance

5. [T+18 hours]

(A) U.S. air forces are now controlled from **E-10A multisensor command and control aircraft** rather than Washington-based personnel. They are escorted by laser-armed **F/A-22 Raptor** fighters. U.S. forces now have a better idea of what's going on in California airspace than the SoCal commanders do.

(B) High-speed **catamaran aircraft carriers** escorted by multi-role nuclear submarines move into coastal waters, launching **F-35 Joint Strike Fighter** and **UCAV** strikes. Cruisers fire non-explosive electrically fired kinetic weapons that exit the atmosphere, re-enter, and impact their targets at hypersonic velocities. Tactical air forces flying F/A-22s use refueling tankers.

(C) Some of the first stealth-on-stealth air battles in history occur between SoCal F/A-22s and federal F-35s. Dueling stealth aircraft are like two men stalking each other on a dark night, each with a gun (missile) and a flashlight (precision radar). The first guy to use the flashlight is likely to regret it. One-on-one dogfights are out. Airplanes fight in groups connected by high-speed data links. One fighter hangs back, out of missile range, and uses radar to transmit target positions to other airplanes in the group.

(D) The ground war begins as transports fly into California airspace. **CAVs** deploy satellite-navigated **supply containers**, which descend by parachute alongside special operations forces who arrive at pinpointed landing targets. Hit-and-run attacks by paramilitaries sympathetic to SoCal inflict significant casualties. Identifying hostile vehicles is difficult, but aided by palm-size UAVs that "tag" them with almost-invisible transmitters.

6. [T+24 hours]

Air dominance is largely achieved. SoCal air forces can no longer operate, except sporadically. Giant **Pelican transports**, carrying six million pounds of cargo, have moved in fuel and weapons for entire tactical air wings. Surveillance satellites under SoCal control are blocked or destroyed by U.S. microsats.

U.S. airplanes operating over California are part of an airborne Internet. High-flying UAVs communicate with satellites and other high-altitude assets by laser and use radio links to exchange data with other

platforms. Small UAVs check and transmit targets at close range; these UAVs are sometimes shot at or down, but that only confirms that the targets they've identified are hostile.

Most civilian casualties take place when noncombatants blunder into engagements between U.S. forces and irregulars on the ground. Some homes and buildings are destroyed by smart bombs rendered dumb by scrambled guidance systems. UCAV operations have to be restricted after a hospital is hit. The most successful UCAVs are Navy-operated: The Navy controls them from the backseats of aging F/A-18F Super Hornets, using line-of-sight links that can't easily be jammed.

7. [T+48 hours]

Ground forces enter the theater—some in **Light Aerial Multi-purpose Vehicles (LAMVs)** (A), short takeoff and landing transports that deliver troops deep into the theater and keep them resupplied. With lightweight **Future Combat System armored vehicles** (B), the infantry is able to match SoCal tanks. Micro- and mini-UAVs (C) accompany the smallest units and operate in urban areas, able to spot the enemy behind houses. SoCal's own **A160 Hummingbird** long-endurance UAVs (D) provide ground surveillance and warn of approaching enemy forces but are not equal to the depth and versatility of U.S. technology. Later, **micro-UAVs** (E), which are equipped with multiple sensors and can fly into buildings, find and root out the last holdouts.

8. [T+72 hours]

Major airfields such as Palm-dale and El Toro (A, B) are secured and used as landing points by Pelicans. By this time, ground units can "shop online" for supplies and ammunition, delivered to their location by the closest LAMV. The last of the rebel forces are subdued.

9. [T+96 hours]

Air Force One—a stealth-modified **7E7 Dreamliner** covered with electroluminescent panels that can match the sky above and the terrain below—delivers the chief executive to LAX to accept the surrender from the local SoCal commander. The Union is whole. Movie deals, it is later confirmed, are inked within hours. ■

What's New



EYE-POPPIN' WHEELIE

Street bike meets Segway in this turbo-unicycle.

When the top eggheads at Bombardier (a Montreal-based company that designs ATVs and jet skis) were asked to envision commuter transportation 25 years from now, they rolled with it. The Embrio Advanced Concept, a hydrogen-fuel-cell-powered, gyro-stabilized vehicle, makes your neighbor's Segway look like something out of the Steam Age. At a stop,

the Embrio relies on a wheeled "landing gear" to stay upright. Above 12 miles per hour, the landing gear retracts, letting you one-wheel along at highway speeds. The unit was meant as inspiration for industrial designers who dream of one-upping Dean Kamen's baby. For now though, this Embrio is still in utero—no working model yet exists. —JENNY EVERETT

Venice project, says his sea gates can withstand waves cresting to 16 feet. To fend off a category-5 storm, Louisiana's gates would need to be reinforced to handle winds upward of 160 mph. They would also have to be taller than those in Venice. "We know that Katrina had in some places a 27-foot storm surge," says Susan Jackson, a public affairs officer for the U.S. Army Corps of Engineers New Orleans District.

THE CHALLENGE

The hurdle is cost, with estimates ranging from \$500 million to more than a billion.

THE STATUS

Army Corps engineers are evaluating several concepts. Preliminary hurricane-protection recommendations are due by early summer.

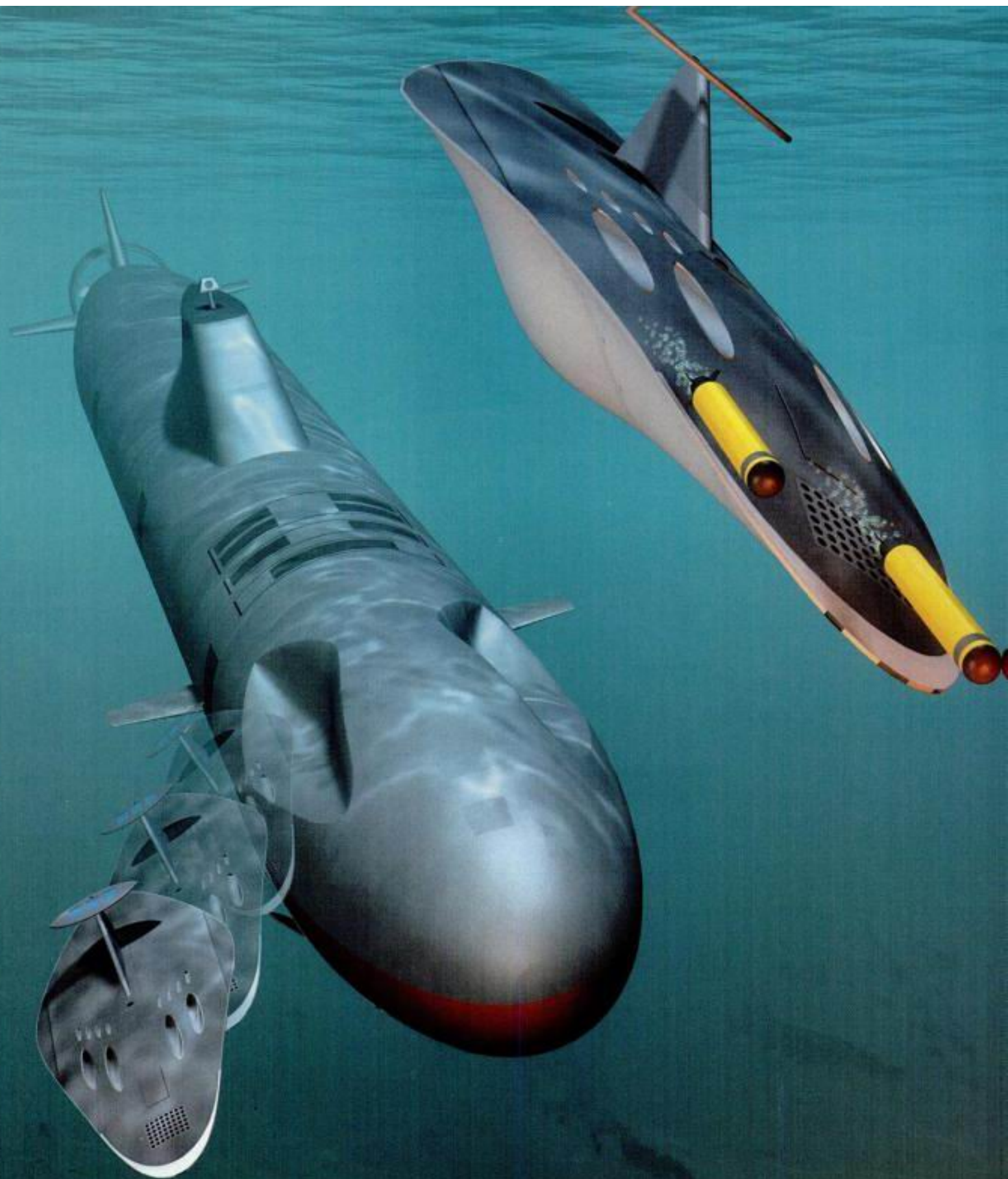
Sensor buoy

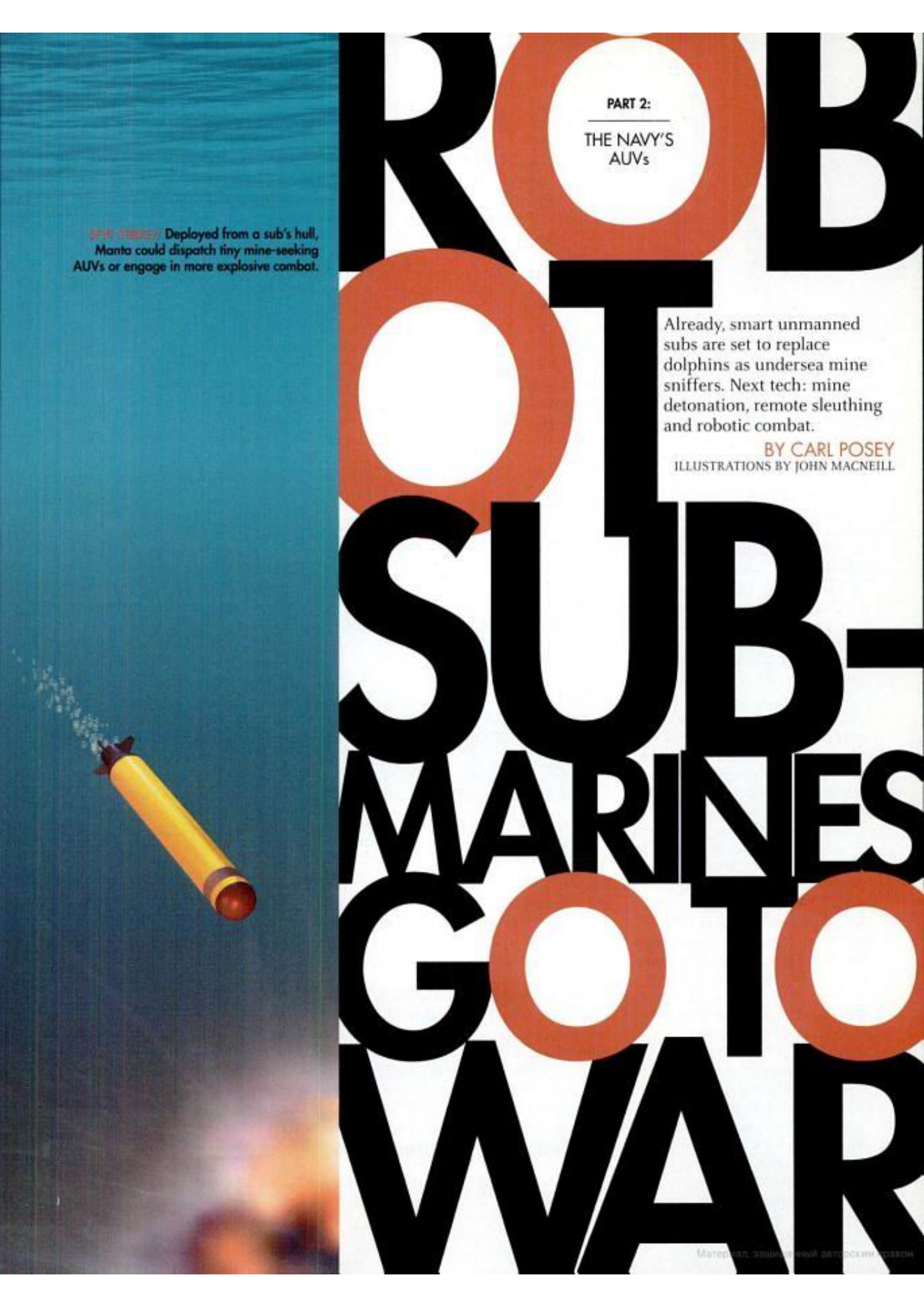
Hollow gate

Concrete housing

WATER WALL To stop storm surges from hitting the city, air would be pumped into hollow barriers, causing them to rise.

Air pump





PART 2:
THE NAVY'S
AUVs

SPIN STORIES Deployed from a sub's hull, Manta could dispatch tiny mine-seeking AUVs or engage in more explosive combat.

Already, smart unmanned subs are set to replace dolphins as undersea mine sniffers. Next tech: mine detonation, remote sleuthing and robotic combat.

BY CARL POSEY
ILLUSTRATIONS BY JOHN MACNEILL

of AUVs instead. The AUVs in the Navy SEALs' tests are programmed before being dropped into the water. Each vehicle dedicates itself to a discrete portion of the harbor, covering it in a series of parallel runs—a tactic called "mowing the grass." Scanning 150 feet in each direction with sonar, the robot subs note the location of all mine-like objects. To keep their bearings, they continually send signals to two transponders that the SEALs have dropped in the water at predetermined locations. (The subs are programmed to know where the transponders are, so by assessing how long it takes for their signals to bounce back, they ascertain their own location.) After a few hours, when the robot subs have covered the entire harbor, they gather at an appointed place to be retrieved.

The AUV used in this operation is the Remus (Remote Environmental Monitoring Unit System), originally developed in 1994 at the Woods Hole Oceanographic Institute for non-military survey work. The institute's commercial spin-off, Hydroid Inc., now produces special versions for military use.

The Remus is 63 inches long and 7.5 inches in diameter. It can stay out for up to 22 hours and specializes in depths of 10 to 40 feet, making it ideal for the shallows of the Gulf. The Navy teams several Remuses together in a system known as Sculpin. Each vehicle can be packed in a metal case that weighs just under 150 pounds, the FedEx maximum for rapid commercial delivery: Sculpin's handlers travel lighter than most camera crews. For now the Sculpin system is designed only to detect mines; human divers would handle detonation.

The Battlespace Preparation AUV (BPAUV), being developed for the Navy by Bluefin Robotics in Cambridge, Massachusetts, operates in the next depth zone, between 40 and several hundred feet. Ten feet long, 21 inches in diameter and weighing about 500 pounds, the BPAUV is no minnow. But Scott Willcox, chief technology officer at Bluefin, says a smaller, more manageable version is in the works. Both the BPAUV and the Remus use side-scanning sonar devices to search for mines buried on or beneath the ocean floor. Transducers on the vehicles' sides dispatch a thin beam of sound waves that extends out like a fan for 150 feet.

Acoustic sensors work best for the job because coastal waters are often turbid, according to Doug Blaha of Marine Sonic Technology in White Marsh, Virginia, which manufactures the Remus's sidescan sonar. "If you walk into a smoke-filled room, you may not be able to see someone across the room," Blaha says, "but you can certainly hear him."

Shallow water isn't just cloudy; it's clogged with the detritus of humanity that sloshes against most of the world's shorelines. "The big challenge is finding mines in these high-clutter areas, filled with human trash—cars, junk, old refrigerators," says Rob Simmons, a program manager at the Navy's Program Executive Office for Littoral and Mine Warfare in Washington, D.C. To help AUVs distinguish a mine from a hot water heater, the Navy is developing more powerful sonar that will provide higher-resolution acoustic images. Also under consideration for AUVs are magnetic gradiometers—sensors that

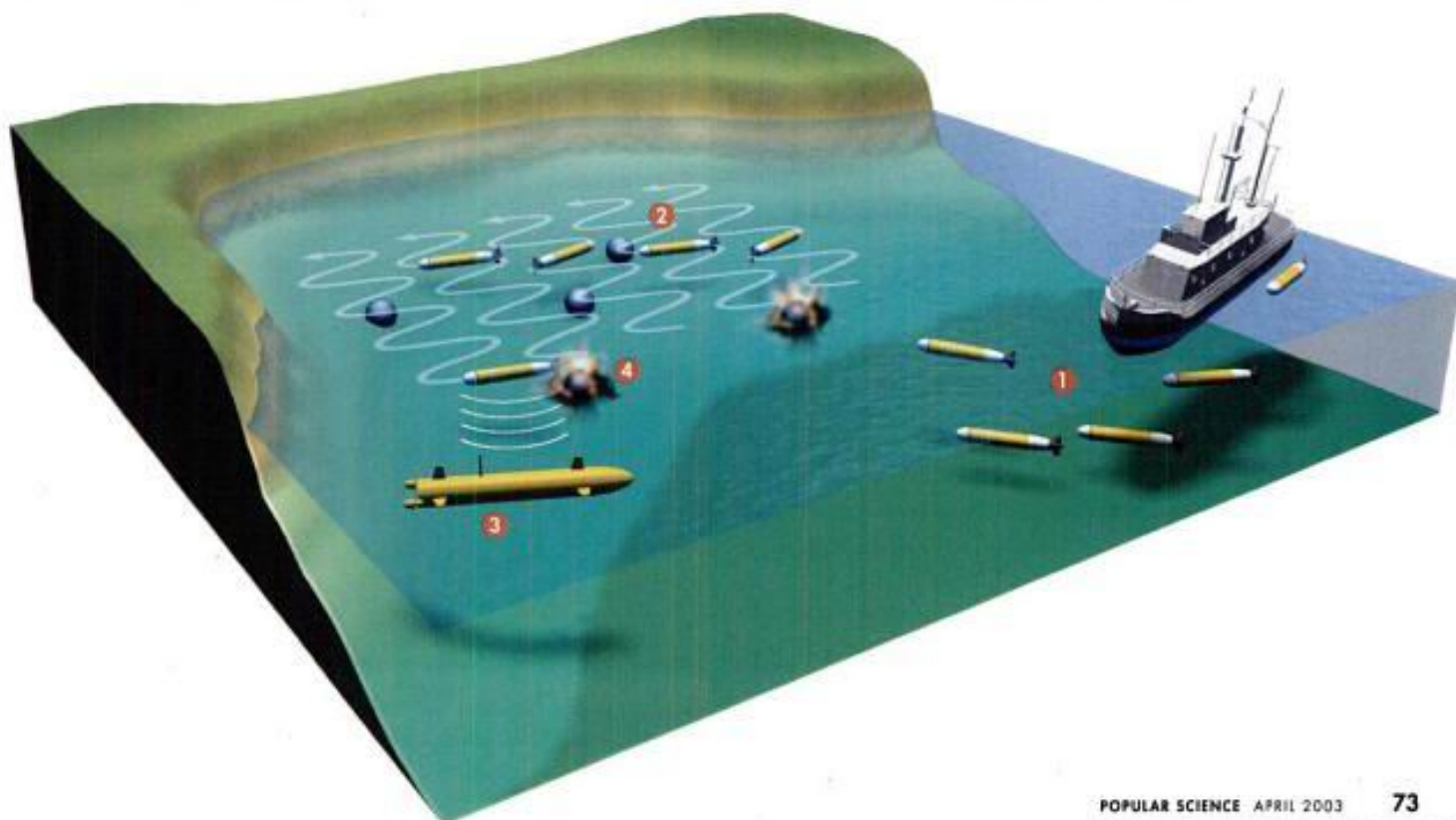
VEHICLE// **FUTURISTIC REMUS**

MISSION//

HARBOR MINE HUNT

An enemy harbor is protected by underwater mines. Typically, an invasion can proceed only after specially trained dolphins mark the mines, followed by a team of Navy divers who swim in to detonate them—a potentially deadly task. In the future, the Navy wants to do this autonomously. For stealth, a common fishing trawler plying outside the harbor could launch small Remus-like AUVs (1).

After they move in, the subs use a sidescan sonar system to search for mines on the murky bottom (2). Because total coverage is so important, the AUVs would continually verify their position using GPS information provided by a larger communication/navigation AUV positioned just outside the harbor (3). Once all the mines have been located, each Remus-like AUV could theoretically position itself over a mine and, after receiving the command, drop a small detonation charge (4). With the mines destroyed, the path is clear for immediate invasion.





VEHICLE// MANTA
MISSION//

COUNTER-ATTACK

In this futuristic scenario, a Navy battle group positions itself far off an enemy's coast (1). Intelligence indicates the enemy has launched two attack subs from a nearby harbor. In response, the battle group's submarine deploys two Manta AUVs. The first Manta deploys a string of sonar sensors around the battle group (2) to give advance warning of an approaching attack sub, while the second

embarks on a search-and-destroy mission closer to shore (3). In the murky shallows of the hostile coastline, the second Manta detects an attack sub. It fires on the sub (4), which fires back before it is hit. Both vehicles are destroyed, though the enemy suffers numerous casualties and the Navy none. Closer to the battle group, the other attack sub trips the sonar sensors (5), alerting the Navy's sub, which quickly advances and destroys it. With both enemy subs destroyed, the battle group is now clear to move toward shore.

use internal magnets to detect changes in local magnetic fields caused by metallic objects—and chemical sensors that would detect explosive materials leaching from poorly made mines.

Mines pose a hazard in deeper water as well. Typically this sort of mine floats near the water's surface, attached to cables moored on the ocean bottom. Here, detection is currently done not by dolphins and divers but by ships or helicopters towing submerged sonar sleds. Neither system, though, is ideal: The ships put themselves at risk by navigating mine-infested waters, and the choppers, flying slow over the water, make an easy target for enemy gunners. The Navy hopes AUVs could one day do the work instead. The area to be covered is vast, so this sort of AUV will be required to stay out for significant amounts of time.

The 28-foot-long Seahorse, specially built for blue-water mine sweeping, will come online this year. It can traverse 300 nautical miles on batteries that will keep it going for up to 72 hours. While the Seahorse, which operates 100 to 1,000 feet below the surface, is ready now, the Navy is working to develop another blue-water AUV by 2004. The Long-Term Mine Reconnaissance System, currently under development at Boeing, consists of two 20-foot-long, 21-inch-diameter vehicles that will be launched and recovered through torpedo tubes. LMRS uses a forward-looking sonar—sending sound waves

out like a movie projector—to spot floating mines, and to steer clear of them and other obstacles while it patrols. Each LMRS vehicle will go out for several days at a time, mapping 50 square miles a day as far as 100 nautical miles from the sub.

Because they are “value added” devices, increasing the Navy's overall work force, AUVs will enable the military to be more proactive. In military parlance, AUVs would enhance “battlespace preparation.” They could be sent out to map the ocean floor in areas of potential conflict—identifying mines, dangerous currents and ideal landing routes ahead of time without alerting hostile countries that their shores are of interest. “We would hope to have the necessary mapping done before war breaks out,” says Martha Head, an oceanographer at the Naval Oceanographic Office at the Stennis Space Center in Mississippi. Today that prep work is done by large oceanographic ships, which makes it expensive, manpower-intensive, and far from stealthy. Transferring the job to small, unmanned, expendable vehicles that could get close to hostile shores without attracting notice would increase efficiency by at least an order of magnitude, according to Swann.

TOMORROW: DETONATING MINES AND MORE

The purpose of mine seeking is to find access routes—both for ships to enter harbors and for special operations forces to land on beaches. In addition to detecting where mines are, it's necessary to determine where they are not. Often the best strategy is to go around a threat rather than confront one. But

 Military AUV photo gallery: Go to www.popsci.com/exclusive

when mines lie in strategic places, they must be removed, and usually the best way to do that is to blow them up.

Making an AUV that can spot objects that appear to be mines is one thing. That's where the Navy is now. Making an AUV that can determine whether an object is a mine and not a million-dollar piece of oceanographic equipment, then destroy it if necessary, is much more complicated. That's where the Navy ultimately wants to be.

One of the vehicles military planners believe might someday be able to destroy mines is the Surf Zone Crawler, an unusual AUV being developed at the Navy's Coastal Systems Station in Panama City, Florida. These small, square, tank-like vehicles are less than a foot tall and have wide tracks that enable them to negotiate rocky ocean terrain. The crawlers aren't as vulnerable to ocean currents as swimming AUVs, which makes them ideal for close-range identification of mines. But they're a long way from being ready. "When it comes down to it, we put our robots in the water and sometimes we get stuck in the mud," says Chuck Bernstein, a Coastal Systems Station engineer.

Another problem: AUVs that are used to blow up mines are likely to be destroyed in the blast. Wernli believes it makes sense to sacrifice one Remus or similar vehicle for every mine destroyed: "If I can take out a mine for \$100,000, that's worth it." But until now the Navy has been accustomed to building complex manned craft it does not want to lose, so the idea of creating expendable vehicles represents something of a para-

digim shift. And it becomes a problematic notion as AUVs get more sophisticated, sporting new kinds of sensors and communications systems. The more gear an AUV possesses, the more it costs, and the less appropriate it is for kamikaze missions. Simmons' rule of thumb: "Don't put it in the water if you can't afford to lose it."

One solution to the problem is a concept known as cooperative autonomy. In a mine-sweeping scenario, for example, high-end AUVs could release cheaper, more primitive machines that could install themselves next to the targeted mines and wait to be told to blow up. "You can still do the job, but each vehicle doesn't have to be as smart," says Bernstein.

Communication will be a key component of such cooperative arrangements. Willcox says Bluefin is outfitting the BPAUV to act as a subsurface server, capable of receiving new mission plans from a ship and relaying them to AUVs down below. The BPAUV will communicate with the submerged vehicles through short-range acoustics, but when it needs to transmit or receive mission-critical information, it will employ a new long-wavelength antenna that transmits radio waves just above the ocean surface. With this capability, the BPAUV could quietly talk to a ship up to 60 nautical miles away.

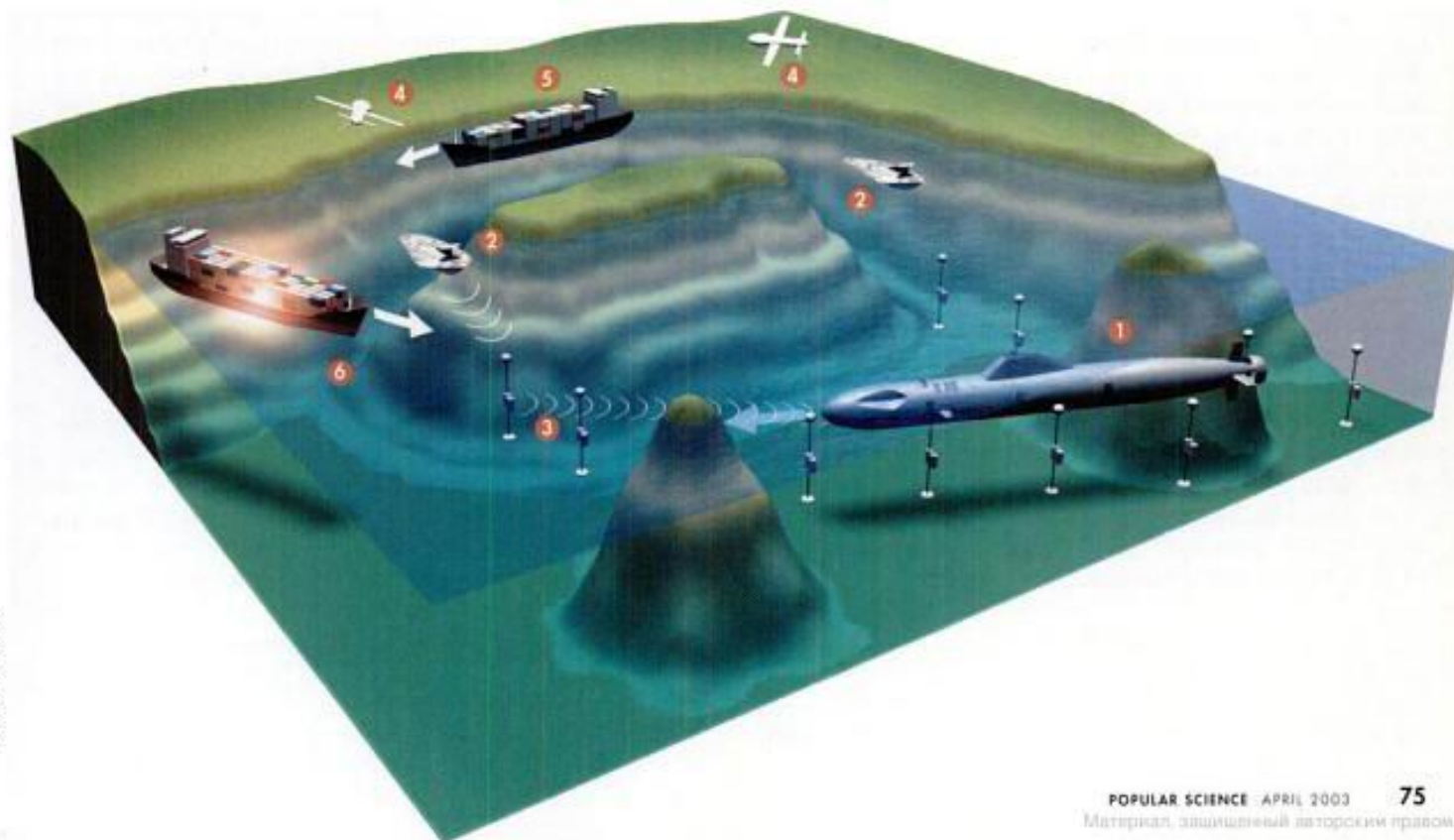
Another way to economize is to create modular AUVs that perform many functions, rather than a panoply of specialized craft. SPAWAR engineers are designing a mission-reconfigurable AUV. The goal is a versatile and far-ranging vehicle, launched and recovered from a sub's torpedo tubes, that

VEHICLE// MANTA
MISSION//

REMOTE INTEL

each fires a small unmanned aerial vehicle from its torpedo tube (4). The drones circle the port, sending images to the Mantas, which in turn transmit them to the sub, where they are monitored by the submarine's commander. When an enemy shipping vessel loaded with contraband leaves port (5), the commander instantly knows. He orders the sub to advance and destroy the vessel in open water (6).

Also desirable to Navy planners is a scenario like this one: A submarine is monitoring an enemy port from its post far offshore (1). To get a better look, the sub deploys two of its Manta AUVs (2). As they travel toward the port, the Mantas release a trail of underwater acoustic buoys (3), which relay limited-distance acoustic communications back to the distant sub. Once the Mantas are in place,



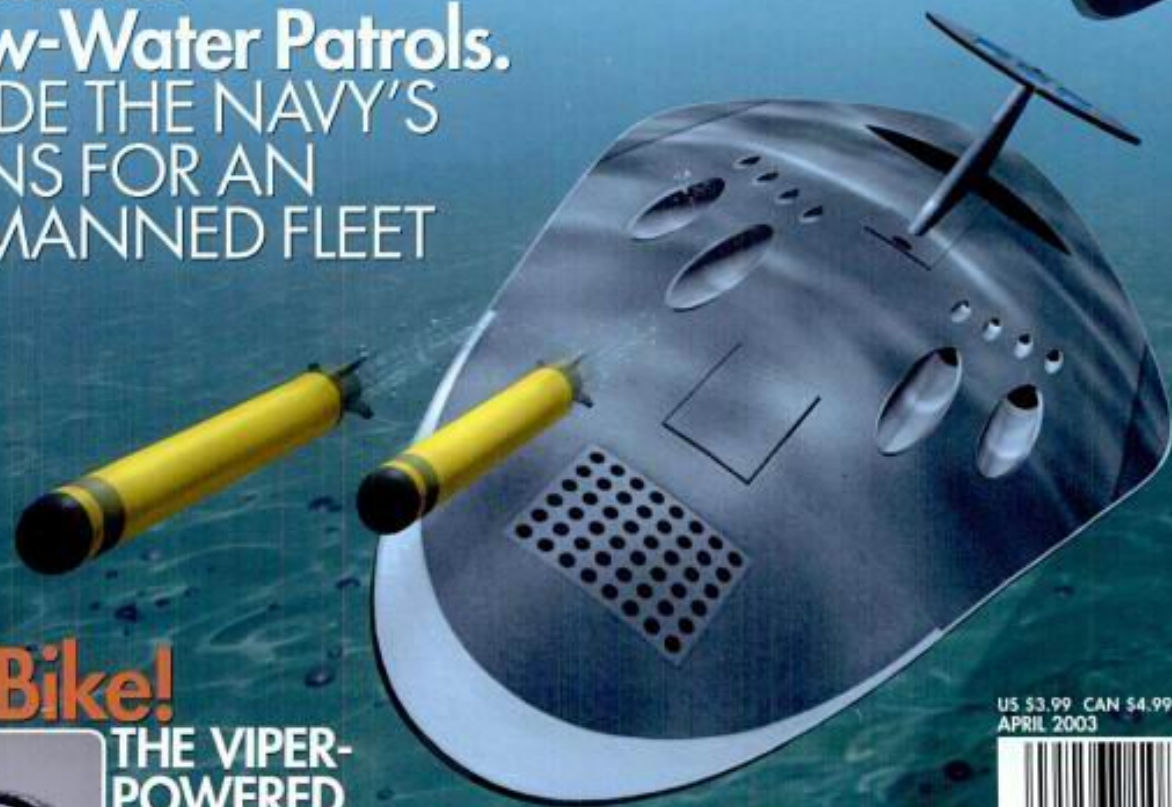
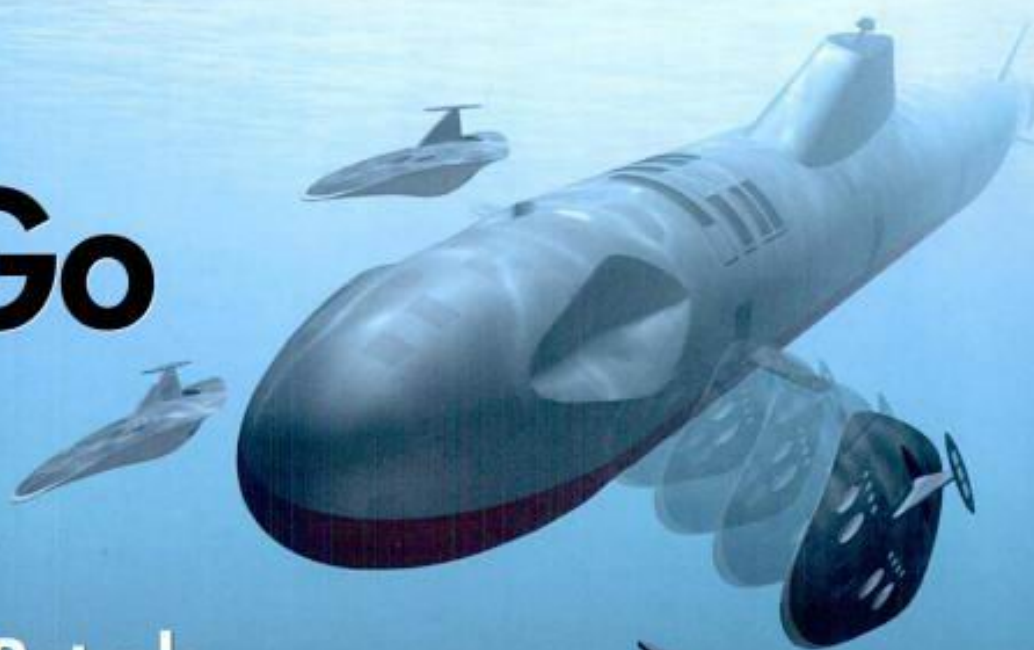
POPULAR science



ISS: Seen from Shuttle Endeavour, Dec. 2002

Robot Subs Go To War

Mine Sweepers.
Sub Hunters.
Shallow-Water Patrols.
INSIDE THE NAVY'S
PLANS FOR AN
UNMANNED FLEET



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HOW EXTREME CAN ROLLER COASTERS GO?

THREE NEW RIDES RAISE THE BAR AGAIN, AND THERE'S NO END IN SIGHT.

Every spring, amusement parks engage in a bit of one-upmanship by unveiling thrill rides that are taller, faster, steeper and more extreme. Making it all possible is new technology like hydraulic launch systems and electromagnetic brakes. The payoff: Coasters that

burst past previously unthinkable height and speed marks, along with new designs that up the adrenaline ante. And though conventional wisdom suggests there's a limit, the laws of physics disagree. In fact, today's roller coasters rarely impart more than 4 to 5 Gs for a second or two—you experience 20 Gs during a good sneeze. "We can definitely get bigger and faster," says Monty Jasper, Cedar Point's vice president of maintenance, who also logged 22 years at rival Six Flags. "It's a matter of who has the money, time and space to flirt with it." This year's biggest flirt: His own Cedar Point, which is unveiling the Top Thrill Dragster, the tallest, fastest roller coaster in the world. —JENNY EVERETT

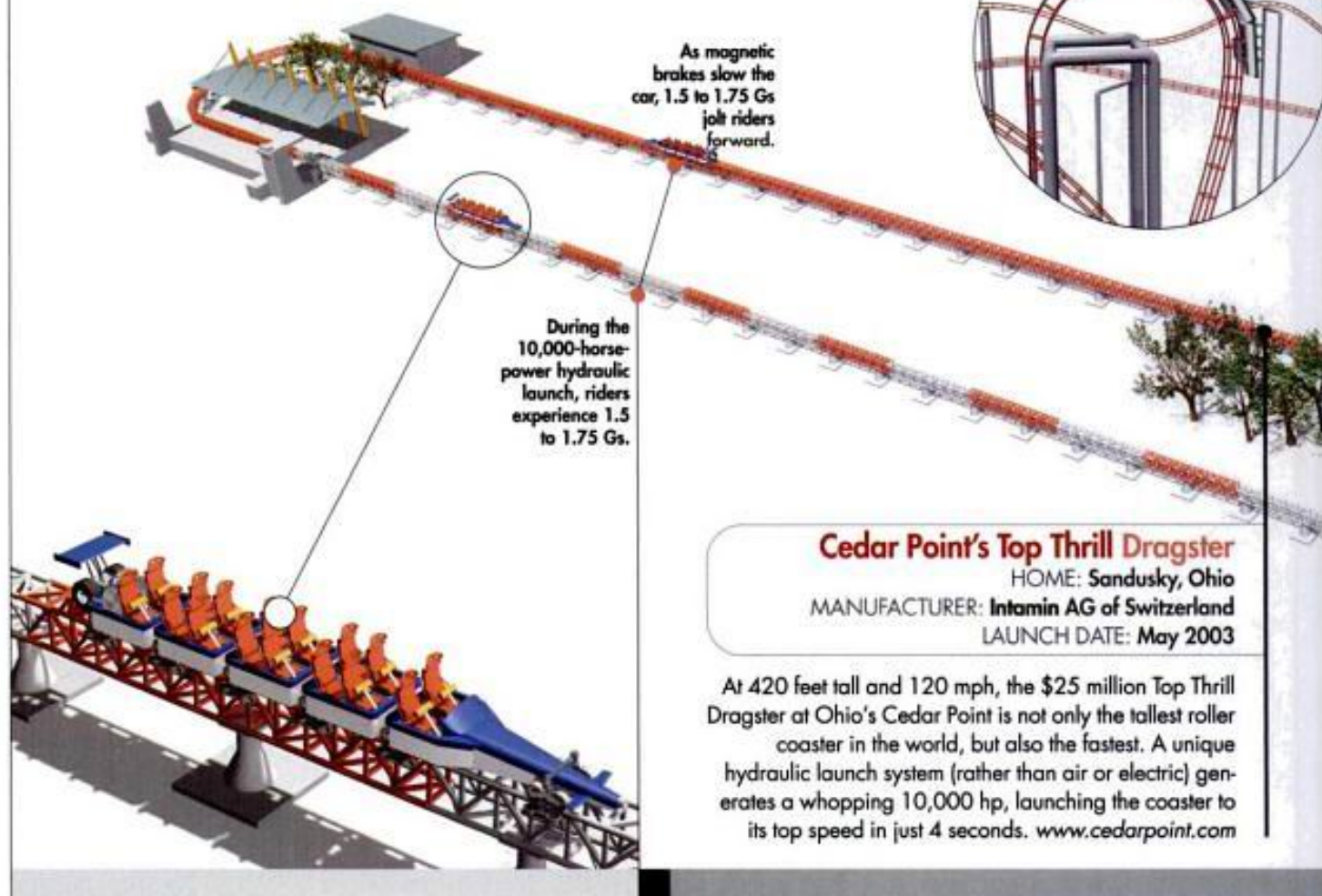
Bon Bon Land's EuroFighter

HOME: Holme Olstrup, Denmark

MANUFACTURER: Gerstlauer Elektro GmbH of Germany

LAUNCH DATE: April 2003

Confirming the buzz in coaster-gossip chat rooms, the EuroFighter (once code-named Tsunami) adds a new page to the coaster design playbook, despite its old-fashioned chain lift. The steel looping EuroFighter features the world's first 95-degree (yes, that's 5 degrees past vertical) plunge toward the ground. www.bonbon-land.dk



As magnetic brakes slow the car, 1.5 to 1.75 Gs jolt riders forward.

During the 10,000-horsepower hydraulic launch, riders experience 1.5 to 1.75 Gs.

Cedar Point's Top Thrill Dragster

HOME: Sandusky, Ohio

MANUFACTURER: Intamin AG of Switzerland

LAUNCH DATE: May 2003

At 420 feet tall and 120 mph, the \$25 million Top Thrill Dragster at Ohio's Cedar Point is not only the tallest roller coaster in the world, but also the fastest. A unique hydraulic launch system (rather than air or electric) generates a whopping 10,000 hp, launching the coaster to its top speed in just 4 seconds. www.cedarpoint.com

WORLD'S TALLEST ROLLER COASTERS



Six Flags' Superman Ultimate Flight

HOME: Jackson, New Jersey, and Gurnee, Illinois

MANUFACTURER: Bolliger & Mabillard of Switzerland

LAUNCH DATE: May 2003

This 60-mph coaster doesn't seem all that impressive at first—its 115-foot hill seems flat compared to the Dragster's—but Superman's one-of-a-kind face-first riding position more than makes up for it. The seats tilt riders into "flying" position before leaving the station, suspending them from the track horizontally. Adding to the thrill, riders come within 10 feet of the ground. www.sixflags.com

Spiraling up the incline at 35 to 45 mph, a vertical 4 to 4.5 Gs press riders into their seatbacks. Coming down, there's a brief period of weightlessness.

TOP THRILL DRAGSTER

420 feet

Cedar Point
Sandusky, Ohio
2003

STEEL DRAGON 2000

318 feet

Nagashima Spaland
Mie, Japan
2000

MILLENNIUM FORCE

310 feet

Cedar Point
Sandusky, Ohio
2000

FUJIYAMA

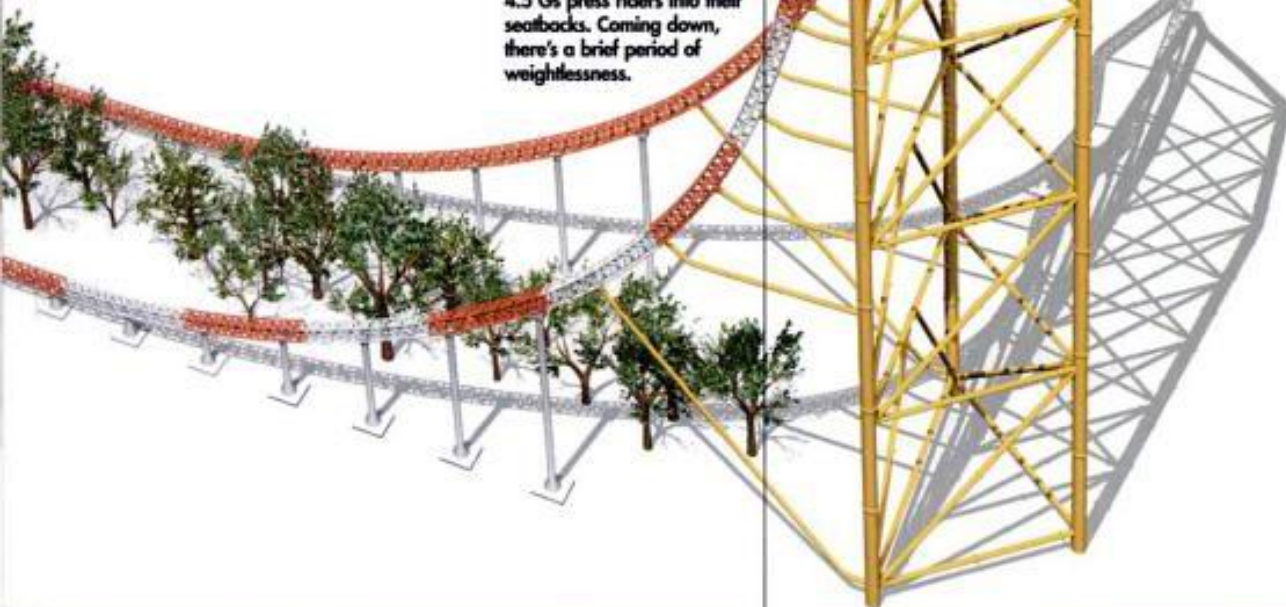
259 feet

Fugikyu Highland Park
Japan
1996

TITAN

245 feet

Six Flags Over Texas
Arlington, Texas
2001





DON'T LAUGH

European studies suggest a building like this could supply much of its own power.

PS DATA

PRICE PLUNGE

\$0.56

Average price per minute for mobile phone service in 1995

\$0.21

Average price per minute for mobile phone service in 2000

\$51.00

Average monthly local phone bill in 1995

\$45.27

Average monthly local phone bill in 2000

Source: Cellular Telecommunications & Internet Association

HIGHWAY SAFETY

LET IT SNOW

A new plow has all the high-tech trimmings.

THERE ARE FEW MORE WELCOME sights on a snowy road than a snowplow, but did you ever wonder how the driver finds the blacktop under all that white powder? It isn't easy. Unless, of course, the plow is equipped with forward-looking radar that watches the road for obstacles up to 300 feet ahead. And with an onboard GPS that locates the plow's position to within an inch, showing both obstacles and the road's boundaries on a head-up display.

The Minnesota Department of Transportation is testing four such plows, and an ambulance and a police car are also being fitted with the system. Drivers look through a transparent screen that makes the road and the display visible simultaneously. "It's like playing a video game in an 80,000-pound vehicle," says John Scharffbillig, field project manager for the Intelligent Vehicle Initiative. "Looking through the display, it's like the lines are freshly painted on the road, even in zero visibility."

But before such plows can be more widely deployed, a network of "correction stations" will have to be built—towers that make it possible for the GPS to keep track of the plows to within an inch. So far, only three have been constructed.—DAN CARNEY

ROAD WARRIOR

A smart snowplow can see the way ahead in any weather.



WHAT'S NEW

EDITED BY SUZANNE
KANTRA KIRSCHNER &
CHRISTOPHER MILLER

Research by Sunny Sea
Gold, Kathryn Leonard,
and Michael Moyer



Double-Duty Ship

A NOVEL PATENT for a cargo ship that works equally well in shallow and deep water is now in the hands of Leary Engineering. The port and starboard hulls are connected by hinges that slide open when the craft is in shallow water (top). The ship regains its deep draft for ocean voyages when the hinges close (right). No shipbuilder has yet signed on to build the vessel. Leary Engineering, Suite 510, 203 Carondelet St., New Orleans LA 70130.

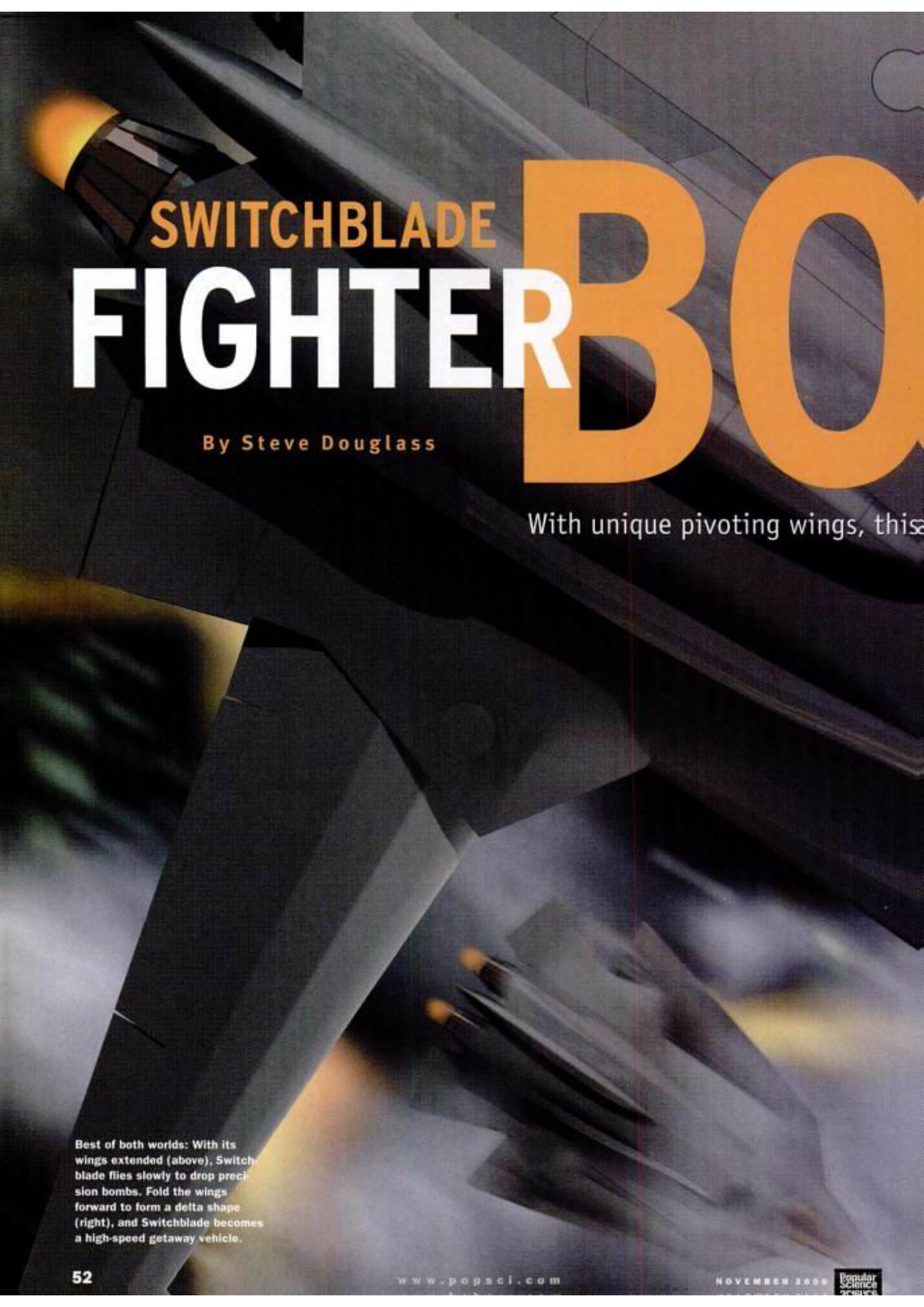


JIM HANDEL



Working Wear

FORGET ABOUT carrying your cellphone or MP3 player. Levi's ICD+ jacket comes with both built in. The devices are tucked away in small pockets and operated with a remote control. Wires within the jacket connect them to headphones and a microphone near the collar. It's available only in Europe for \$600 to \$900. www.eu.levi.com



SWITCHBLADE FIGHTER

By Steve Douglass

BO

With unique pivoting wings, this

Best of both worlds: With its wings extended (above), Switchblade flies slowly to drop precision bombs. Fold the wings forward to form a delta shape (right), and Switchblade becomes a high-speed getaway vehicle.

ILLUSTRATION BY JOHN MACNEILL

MBER

secret military airplane leads a double life as both a bomber and fighter.

JACK OF ALL TRADES

ARTIST'S RENDERINGS, based on Northrop Grumman patent drawings, show a forward-sweeping wing that can assume multiple positions for different types of flight.



With its wings tucked in, Switchblade can dash away at speeds up to Mach 3.



With its wings in an intermediate position, the aircraft is extremely maneuverable during combat encounters.



With its wings swept fully aft, Switchblade flies at slower speeds to drop bombs precisely on their targets.

ON MOONLESS NIGHTS, a secret aircraft taxis out of a remote hangar complex at an Air Force base in Nevada. The security lights at the base are dimmed as the aircraft rolls out onto the active runway. Under cover of darkness, the fighter-size aircraft takes off on a training mission over the sprawling Nellis Bombing Range.

Sources tell us that this mysterious plane, officially called the Bird of Prey, will soon be declassified. But for now, not much is known about the aircraft except that it uses a unique swing-wing mechanism to play a variety of military roles.

As far back as 1989, aviation aficionados began hearing rumors that the Pentagon was developing a new aircraft to replace its aging fleet of swing-wing F-111s, which retired permanently in 1995. The F-111 was a medium-size bomber capable of defending itself as a fighter and then speeding away from enemies at more than 1,600 miles per hour.

A few years later, reports surfaced of a new swing-wing aircraft sighted near Cannon Air Force Base in New Mexico, and at Langley Air Force Base in Virginia. High-ranking officials are said to have gathered in secure hangars at the two air bases for a sneak peek at the new aircraft. It was also observed circling high over Amarillo, Texas. POPULAR SCIENCE investigated the reports for an exclusive story on the Bird of Prey in 1995.

Since then, we have learned that the aircraft is not a standard swing-wing plane as first reported, but instead employs a unique forward-sweeping wing apparatus. Because the wing pivots like a blade folding into the handle of a pocketknife, pilots have nicknamed the aircraft Switchblade. The clever design makes the aircraft versatile enough to serve as both a fighter and bomber.

Switchblade's wings are attached to the aircraft's fuselage at a pivot point toward the rear of the plane. When the wings are fully extended,

the aircraft can slow to drop precision weapons or to land on short, unimproved runways. With the wings swept farther forward, the aircraft becomes a highly agile combat platform. And when the wings are swept fully forward, with the trailing edge transformed into a leading edge, the aircraft assumes a delta shape perfect for dashing away at speeds up to Mach 3.

Drawings and a description of just such a pivoting wing appear in U.S. Patent 5,984,231, which states that "the aforementioned apparatus may be used in a method to configure the aircraft for flight in a desired flight regime. This method includes moving

the wing to an optimal position for the desired flight regime." In other words, the Switchblade plane can take on multiple missions simply by reconfiguring itself in midflight.

Northrop Grumman Corp., a longtime builder of secret aircraft based in Los Angeles, filed the patent in November 1999. Declassification usually follows within a year of such a patent filing.

Switchblade builds on earlier work that was done by both Northrop and the Grumman Aircraft Corp., which merged in 1994. Previously, Grumman was responsible for the development of the X-29, an experimental fighter-size aircraft with forward-swept wings. The wings made the X-29 look as though it was flying backward, but they also made the aircraft exceptionally maneuverable and resistant to stalls—even at attack angles as high as 45 degrees.

An aircraft with forward-swept wings is inherently unstable, which is what makes it so agile. But for an attack aircraft, this wing configuration



Switchblade crews are believed to wear this patch, which hints at the aircraft's shape.

Technology Watch

Aviation • Computers • Energy
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Robotics • Space • Transportation



NASA and the Air Force see laser-powered rockets in their future.

Riding Light Beams To Space

A radical new propulsion system could make future space launches look more like laser shows than fireworks displays. Using a ground-based 10kw laser, scientists at White Sands Missile Range, in New Mexico, have shot pie-plate-size capsules up to 100 ft. aloft.

"It's comparable to what the Wright brothers did at Kitty Hawk," says Jonathan Campbell, of NASA's beamed energy program. "We've just demonstrated that the

principle works. Nobody thought it could be done."

Tests were performed by zapping 20 laser pulses per second at the bottoms of 8-in.-tall, 2-ounce, cone-shaped capsules. Some were made of aluminum, others

aluminum-lithium and titanium. When the concentrated beam of light hits the highly reflective base of the capsule, the air around it gets extremely hot and expands explosively, providing the thrust. Amid popping that sounds

like a string of firecrackers, the capsule zooms upward, then silently falls back. A technician catches the capsule with a fishnet.

Laser propulsion could have its first practical application boosting lightweight instrument packages up to 100 miles.

Even with full funding, researchers say it would take at least five years for the maiden launch. So far, NASA and the Air Force have spent less than \$1 million on the joint project.

Despite these modest beginnings, the future looks bright. Leik Myrabo, a researcher with the Rensselaer Polytechnic Institute, in New York, envisions not only spacecraft but laser-propelled airplanes.



June Highlights

Miniature Surgical Robot—Cutting with instruments could speed recovery.

■ **Air Stops Water**—Inflatable dam holds back floods as well as steel and concrete.

■ **Artificial Blood For Dogs**—Disease-free substitute promises to save humans too.

Editor: Jim Wilson
Reporters: Stefano Coledan,
Brad Dunn, Scott Gourley,
Richard Schrader

Consider the top technological advances of the past 100 years. The airplane? Sure. Antibiotics? Yep. The television, computer, and Internet? Absolutely. Strangely absent from most people's lists, however, are technologies for the home. Advances like wood framing, the stove, heating and air conditioning, and indoor plumbing date back well over 100 years. So while technological revolution has hit nearly every aspect of life over the past century, our homes—where we spend most of our time—have strangely been left behind.

That's about to change, as new technologies are poised to radically alter how we live. Most, like self-cleaning surfaces and appliances that work together to complete tasks, will make our lives easier. Others, such as power-generating fuel cells, will save us money. And still others, such as visual reminders to turn off the stove or to take medication, will protect our families.

In this special section, we look at how new technologies for the home will change our lives over the next 25 years. But you won't have to wait that long to see the benefits: Many of these innovations are on their way today. Technology, finally, is heading home.—William G. Phillips

Home Neat Home

THE HOME of the future is all about innovative technologies that will keep residents safe and comfortable—and save them money in the process. A look at some of its key features.

Networked wiring allows residents to control the home's various systems via the Internet

Bathroom mirror displays each person's daily schedule, along with health information

READER POLL RESULTS To learn what people think about the future of home technology, we polled visitors at our Web site, www.popscl.com. Some results are printed throughout this special section. The entire survey appears in FYI.

ILLUSTRATION JOHN MACNEILL

WHAT'S NEXT: home

Electrochromic glass, controlled with a dimmer, turns opaque when electric current is applied

Structural composite lumber is stronger, lasts longer, and uses smaller pieces of farm-grown trees instead of ancient timber

Sensors alert homeowners if the roof springs a leak or if mold starts growing in the ductwork

By Charles Wardell

IN A converted industrial building belonging to the Massachusetts Institute of Technology's Architecture Department, graduate student Jose Duarte is designing the home of the future. Or rather, his computer is designing it. A new type of software, which Duarte developed as part of his thesis, guides him through the questions an architect would ask a homeowner—the size of the family, their living habits, the rooms they want, how much they can spend. When the computer is done interviewing him, Duarte clicks his

From self-cleaning surfaces to fuel cells that create electricity from water, homes are going high-tech.

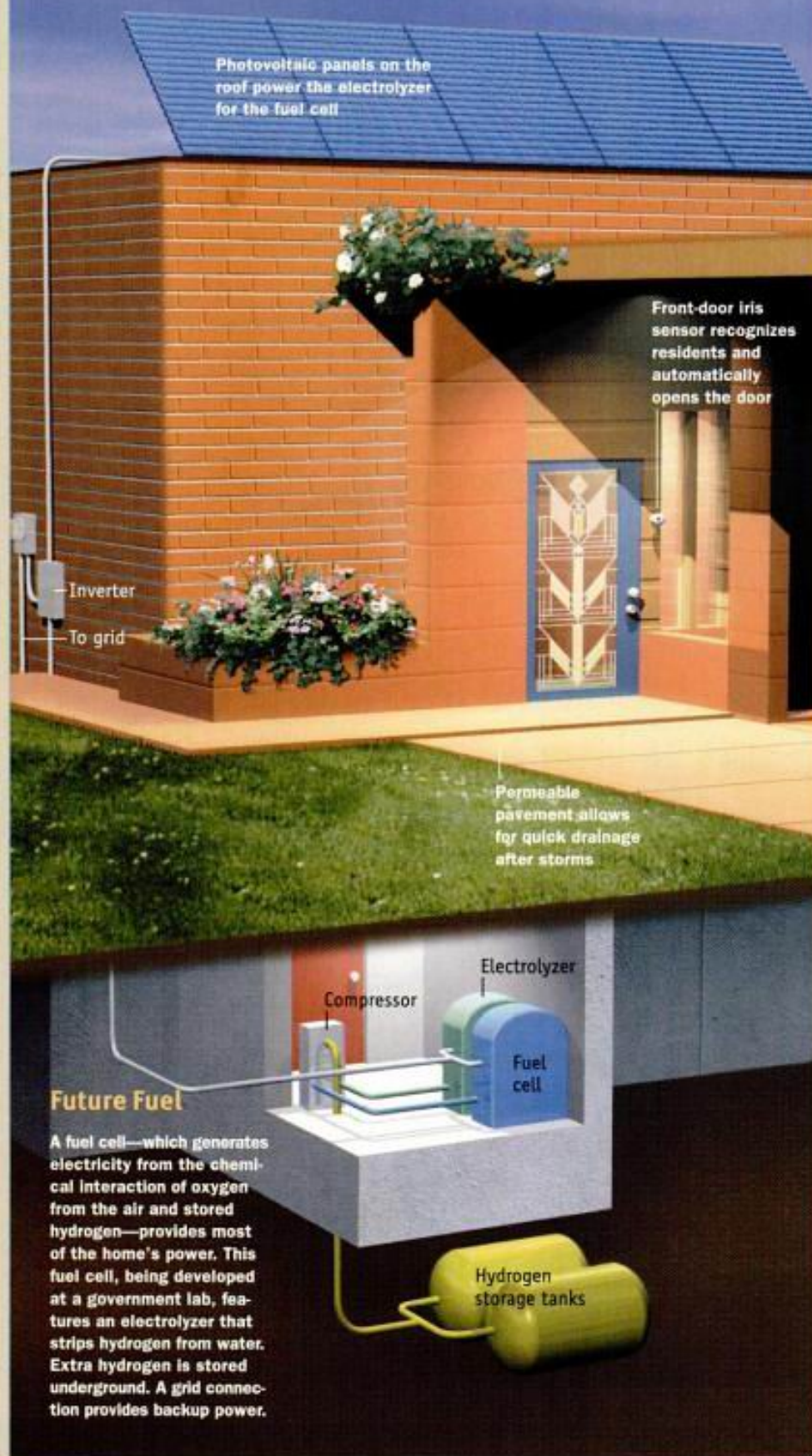
Home of the Future

38%

think homes will
look much more
futuristic in 2025

POLL FLASH
www.popsci.com

"Rather than making houses bigger and bigger, let's make them better and better."—Steven Winter



mouse and sits back in his chair while the computer creates a text description of the home. He makes some minor changes, clicks again, and the computer draws a 3-D model of a house. "I call it the virtual architect," says Duarte, who hopes eventually to find a financial backer to help him market it to builders and homeowners.

Make no mistake: This is no clichéd "futuristic" home. Duarte's current software draws in the style of Siza Malagueira, a renowned architect from Portugal. But the software could be easily programmed for any architect or architectural style. The goal is to offer buyers whatever design meets their fancy, from Frank Lloyd Wright to American Carpenter Gothic. Within 10 years, Duarte hopes his creation will make "architect-designed" custom homes readily available to the average homebuyer.

Welcome to the home of the future. While the facade will be one your grandparents would feel comfortable with, the structure will be a child of technology. Some of the technologies, like the virtual architect, will give you unprecedented control over the home's design and construction. Others, like self-cleaning surfaces, will give you more freedom over how you live your life. And still others, such as clean-burning fuel cells that power the home from the basement, will minimize the home's impact on the environment. And while these technologies may eventually make a difference in existing houses, they're likely to show up first in new homes.

Many of these technologies are still in the lab, while others await a mass market. But will anyone want them? After all, the homebuilding process has changed little in the past century. Many people are quick to blame builders for this, but homeowners

DETROIT'S NEW 80 MPG CARS

<http://popularmechanics.com>

JUNE 2000

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**STEP-BY-STEP
GUIDE TO
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FROM
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The chief attraction of the moon is recreation in low gravity, which will make visitors super-athletes.



POSTCARDS FROM THE MOON



A lunar vacation isn't as far-out an adventure as you think.

BY JIM WILSON, Illustration by Paul DiMare

► When Apollo 14 astronaut

Alan Shepard teed off on the moon, television viewers got more than a lunar golf lesson. They also caught a glimpse of the best reason we would have for revisiting our celestial neighbor. Forget about building deep-

COVER STORY

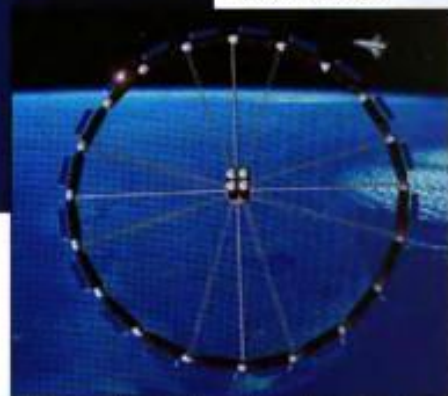
space telescopes, mining helium-3 for fusion reactors or any of the other practical reasons for establishing a lunar colony. Earthlings just want to have fun, and there is no place here that can match the excitement "out there." Just getting

there would be a kick in the pants as you blasted off on the adventure of a lifetime. Once on the moon, which exerts only one-sixth the gravitational tug of the Earth, you could break the high jump, broad jump and pole vault records without breaking a sweat.

While you can't book a lunar getaway today, the prospect of vacationing on the moon isn't a flight of imagination either. Encouraged by the growing popularity of the extreme adventure craze—climbing Mount Everest, teasing killer sharks from inside steel cages, that sort of thing—space entrepreneurs took a poll to learn if they could sell un-Earthly vacations. An



The raw material for orbiting and lunar hotels might be space shuttle fuel tanks, which are currently discarded and burn up on re-entry.



astounding eight out of 10 Americans under age 40 said they would go. And, one in 10 would dig deep into their pockets, paying as much as a year's salary for a ticket.

Sensing the launch of a new growth industry, Rochester Institute of Technology in New York and George Washington University in Washington, D.C., have set up programs to train future space tourism experts. Students at the University of Southern California in Los Angeles can learn the fine points of building lunar habitations from world-renowned space architect Madhu Thangavelu. Exotic though their specialties may be, these graduates will probably get to work in their fields. Two major hotel chains and a major Japanese construction company have announced plans for fixed and flying lunar hotels.

"Right now we're on the edge of the technological knife. As soon as Americans see the first commercial astronaut in space, there will be a realization that the realms out there are not the exclusive property of NASA," says David P. Gump. As the president of LunaCorp of Arlington, Va., (www.lunacorp.com) which was founded in 1989, he is one of the founding fathers of the space tourism trade.

Gump sees lunar tourism following the same trajectory as travel to exotic locations here on Earth. "At first it was only the movie stars who

could fly a DC-3 from coast to coast. Then airline travel became a mass market." For its part, LunaCorp is building the 21st century equivalent of the 3D viewers that brought the wonders of the Wild West into the parlor and awoke a wanderlust in 19th century imaginations. Being built in cooperation with the Robotics Institute of Carnegie Mellon University in Pittsburgh, Pa., the LunaCorp Icebreaker is a wheeled robot that will allow Earthbound travelers to steer a high-tech moon buggy over the dusty lunar soil.

X-Prize To Orbit

The vicarious thrills provided by a ride on the LunaCorp Icebreaker, which is expected to arrive at the moon's south pole in late 2003, could be just the ice-breaker the space tourism industry needs to get its plans off the drawing board. "People really do want to get into space," says Apollo astronaut Buzz Aldrin, who is also a LunaCorp adviser. "But they are prevented by the cost." Depending upon whether you fly on a Chinese rocket or NASA space shuttle, the price ranges from about \$2000 to \$10,000 a pound to reach orbit. The consensus is that it will need to come down to below \$100 before serious space tourism can begin.

Rockets that take tourists from the Earth to the moon aren't likely to have NASA nameplates. Except for encouraging rhetoric, the space agency has written off lunar exploration and support for space tourism. Instead, the road back to the moon is being driven by an unusual competition that harkens back to the early days of aviation, when the impossible dream was to fly an airplane across the Atlantic Ocean. In the true spirit of The Spirit of St. Louis, the X-Prize Foundation has set up shop in the city that Lucky

Lindy made famous and raised \$10 million in prize money for a modest but essential first step to the moon.

To claim the gold, a privately funded organization must fly three people to an altitude of 62 miles. Then,

and this is the hard part, it must make a second trip within two weeks. So far, 16 teams are officially in the running. "Humans do their most creative and best work when they're competing," says competition founder and chairman Peter Diamandis. "The X-Prize is looking to heat things up again by introducing a constructive type of



For Science News And Story Updates

Check the Science channel on the PMZone Web site at popularmechanics.com/science

"We've taken the space resort concept to the next level by showing the public how livable space can be."

competition amongst the top rocket scientists and entrepreneurs from around the world."

Entrepreneurs have their eyes on the X-Prize because of the unusual economics of space tourism. The costs of travel on Earth are pretty much proportional to distance. It costs about twice as much to drive 100 miles as 50. A ticket from New York to Hong Kong is more expensive than a ticket to Detroit. In space travel, most of the costs are "front loaded" into the first seconds after liftoff, when the rocket gobbles most of its fuel, literally kicking you into space. Liftoffs will be a fast and furious thrill, but from the perspective of tour operators, not exactly a money machine. Since staying in space costs only a tiny fraction of what it costs to get into space, the profits in space tourism will be made on long trips. And longer trips



LunaCorp would create virtual tours with live video feeds from a robotic lunar rover.

ris wheel, the resort will rotate very slowly, about once a minute. This will simulate one-third to one-half the gravity experienced on Earth.

Dining, entertainment and living quarters will be located along the outer section of the ring. "We've taken the space resort concept to the next level by giving the public the opportunity to see just how livable space can be," says Meyers.

Successful Las Vegas hotel owner Robert Bigelow sees a flaw in Earth-orbiting hotels that can be summarized in one word: boring. His solution is a more interesting orbit, one

that would take tourists around the moon. The owner of Budget Suites of America, Bigelow has formed a new company, Bigelow Aerospace, to advance his idea. He tells POPULAR MECHANICS that he plans to invest a half billion dollars in technologies needed to develop an orbiting hotel that would shuttle between the Earth and the moon. Preliminary plans call for the Earth-to-moon hotel to be a half-mile long. It would slowly rotate to simu-

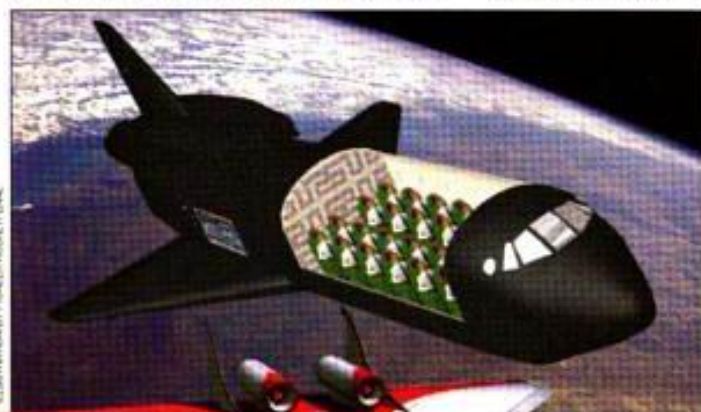
late about 40 percent of the gravity here on Earth. A staff of 50 could be welcoming its first flight of 100 guests aboard in about 15 years. The exact departure date will depend upon the availability of a low-cost launch vehicle, perhaps a design encouraged by the X-Prize.

Lunar Luxury

A hotel that circles the moon will be a prelude to a hotel on the moon. Peter Inston, a British architect who has designed hotels for the Hilton chain, has proposed a sprawling 5000-room domed structure. It would be powered by the sun and receive its water supply—hotels use lots of water—from lunar ice that may exist in polar regions. Former NASA engineer Gregory Bennett, who now runs Bigelow Aerospace, worked out plans earlier in his career for pressurized clear plastic walkways so tourists could venture onto the lunar surface.

Although they are still at the satellite-launching stage of developing a space presence, the Japanese have announced they plan to be a major player in lunar recreational development. Shimizu, a Japanese construction firm, says it has invested \$3 million in plans for luxury lunar condominiums.

"We look forward to lively competition in the coming profession of commercial space architecture," says Space Island's Meyers. "It's a field crying out for new leaders—and are they going to get famous." **PM**



A lunar vacation would begin by flying into orbit.

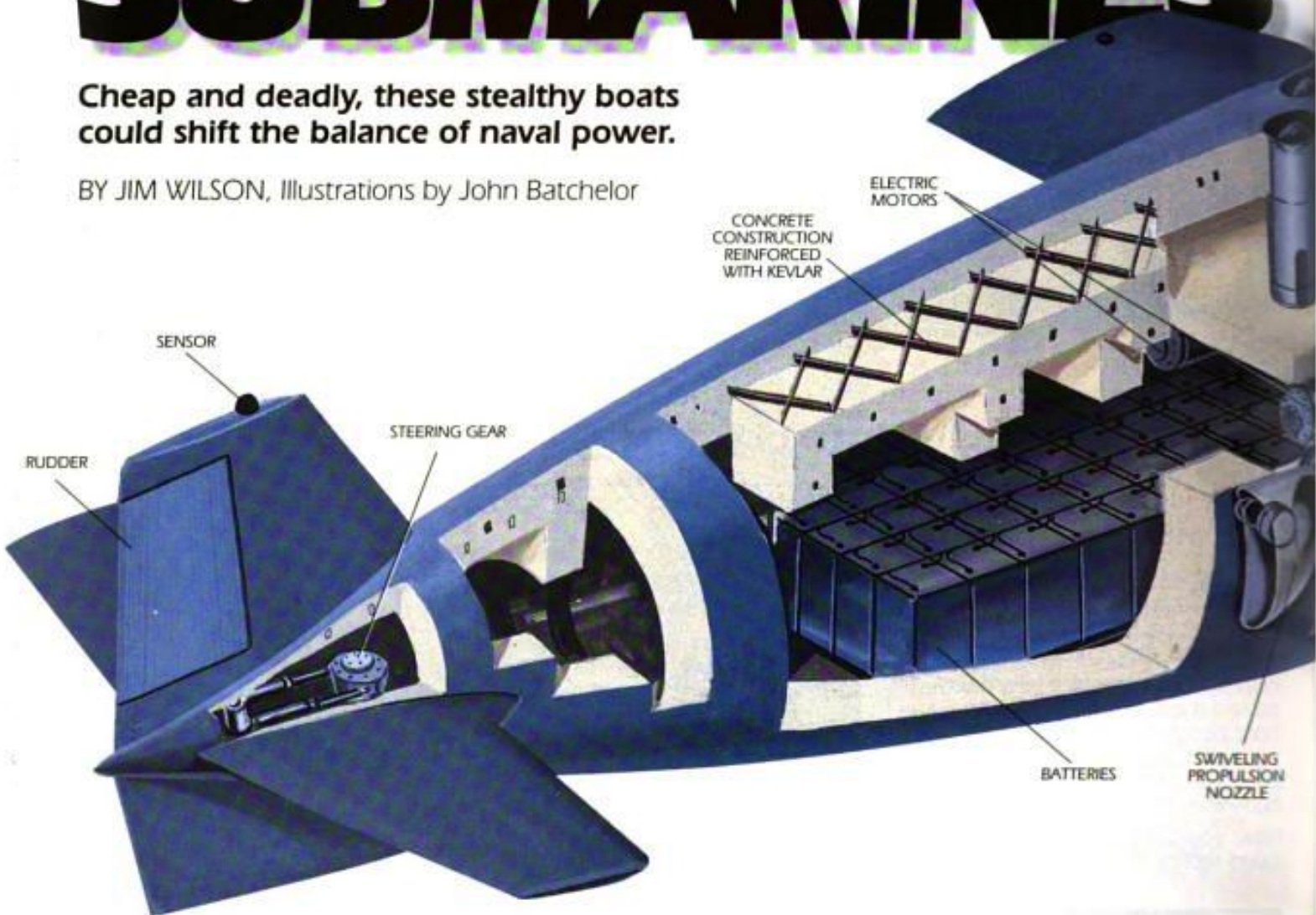
will require more than a spacesuit and a place to sit. Industry experts say that experiences with *SkyLab* and *Mir* have solved these problems. "The idea of living comfortably and safely in space is quickly becoming a reality," says Gene Meyers, president of Space Island Group (SIG) of Los Angeles. "Given the availability of proven technology, it's no longer a matter of how, but when."

Late last year, SIG unveiled the interior design for an Earth-orbiting hotel. Meyers envisions a space resort constructed from the empty external fuel tanks of NASA space shuttles. Assembled like a giant Fer-

CONCRETE SUBMARINES

Cheap and deadly, these stealthy boats could shift the balance of naval power.

BY JIM WILSON, Illustrations by John Batchelor



Concrete submarines could

be the dumbest idea in naval history. Or, they just might give poor nations a way to checkmate their richer, more technologically savvy foes.

Going to sea in what amounts to a hollow rock is actually a well-proven idea. Concrete ships carried cargo

DEFENSE

during both world wars. College kids hold an annual concrete canoe race. And you'll find concrete barges, houseboats and sailboats in scores of marinas.

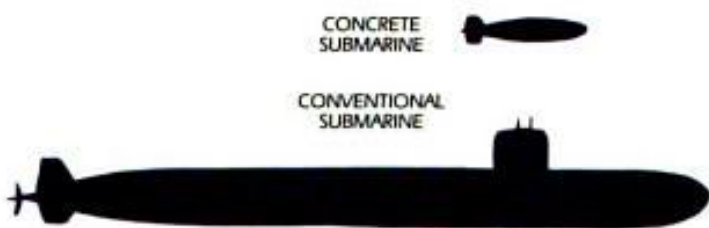
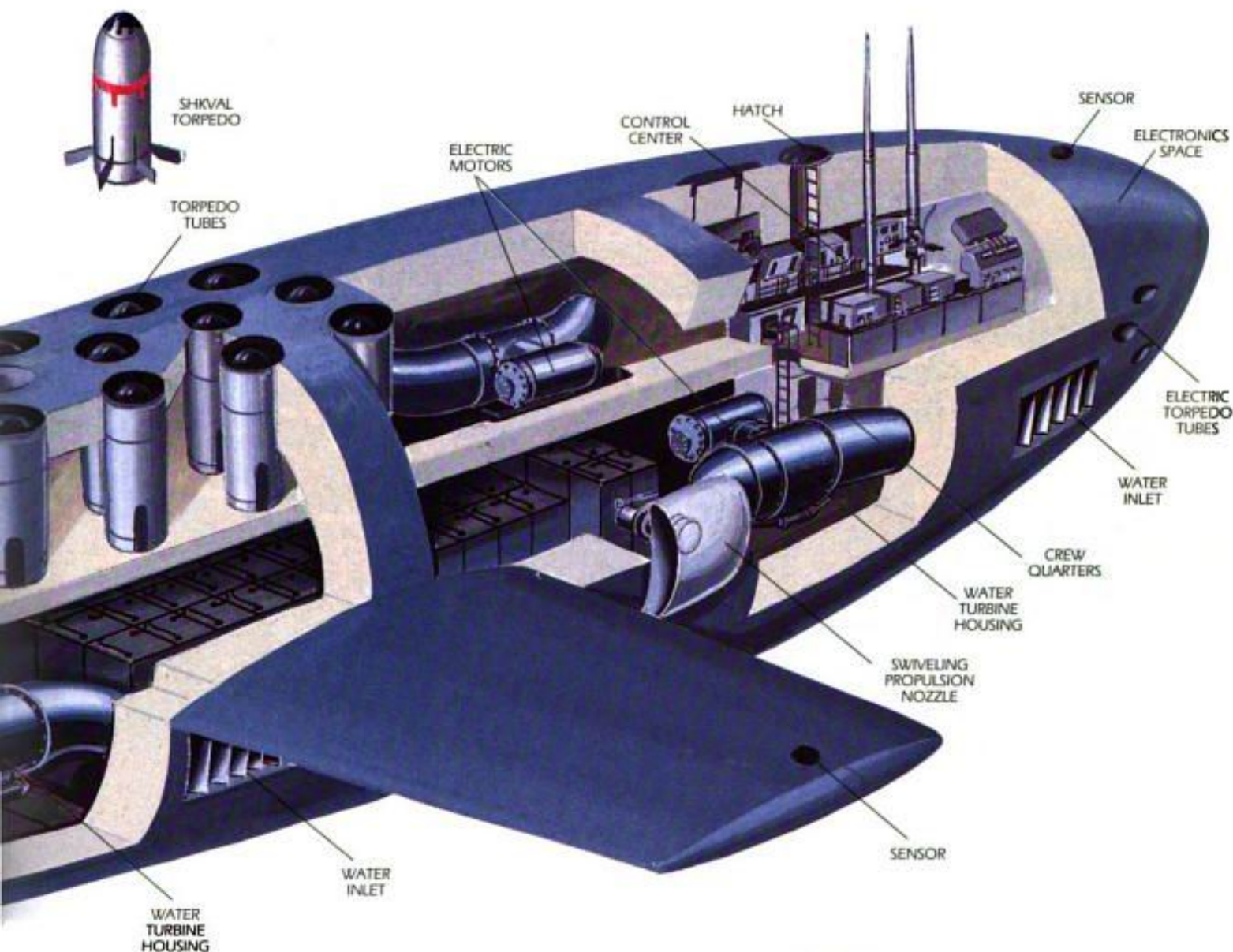
Now the Russians want to take the idea to a new low—with concrete submarines. Called C-subs, these 6-man vessels (shown above) will differ from today's submarines in several important ways. Conventional

submarines float until they take on water. C-subs will stay afloat by using four electric turbine pumps to propel water downward. The swiveling nozzles that direct this flow also will enable the C-sub to move.

C-subs will also fight differently. Conventional submarines prowl the seas. On a typical patrol, a C-sub will sink offshore, waiting for enemy ships to pass overhead. Then it will fire vertical-launch torpedoes. Because concrete is strong in compression, C-subs could sink well below the 1800-ft. "crush depth" for steel, according to the British Ministry of Defense (MOD). And on sonar displays, the concrete will be hard to distinguish from a sandy sea bottom.

MOD knows about C-subs because they resemble an idea floated by German marine engineer Heinz Lipschutz

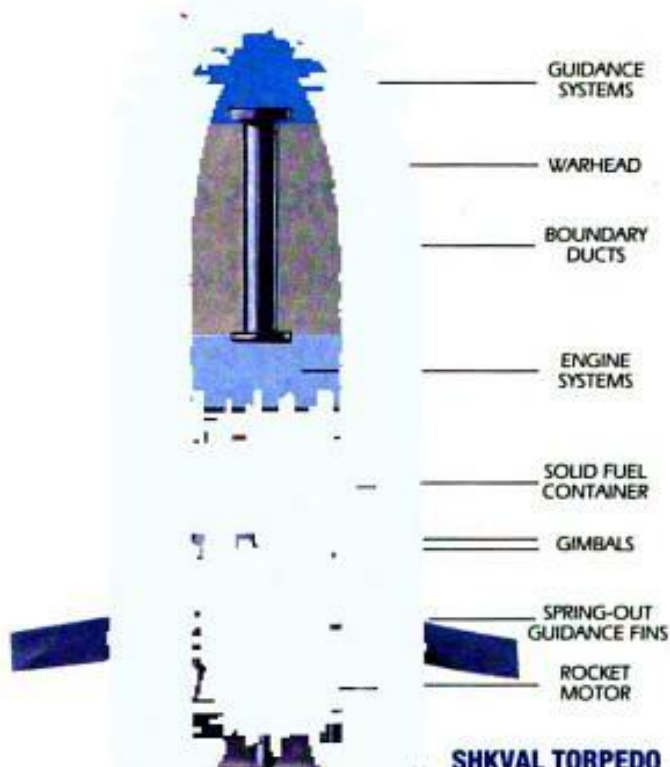
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in 1957. The Royal Navy wasn't interested then, but MOD thinks that the new Russian C-sub has a feature that poor countries will find hard to resist—rocket-powered torpedoes. Developed in the early 1990s and code-named Shkval—Russian for squall—they can travel through the water at 230 mph, about four times as fast as conventional torpedoes.

Shkval-launching C-sub's could shift the balance of naval power, cautions British defense analyst Julian Nettlefold: "With these craft being potentially so cheap to make, there is the danger of countries such as Iran and Libya using them to threaten American carrier groups or to barricade certain ocean routes."

A Shkval torpedo reaches high speeds by diverting some rocket thrust through its nose, thus creating a low-friction path.



SHKVAL TORPEDO

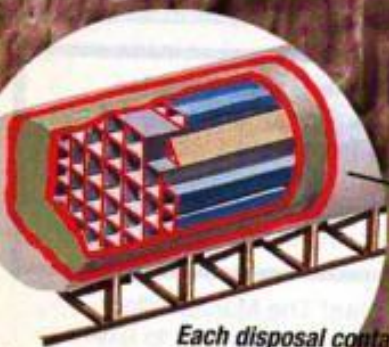
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PLUTONIUM

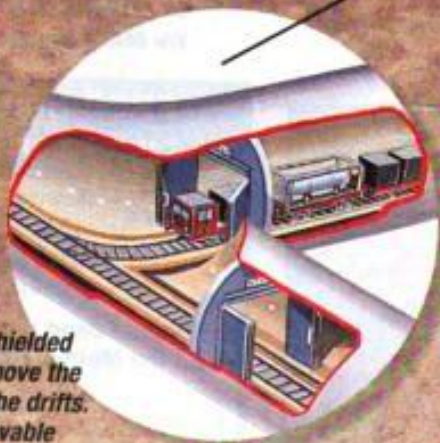


The repository will have two air-circulation systems separated by movable airlocks.

Depending on conditions, the tunnels, or drifts, in which waste casks are placed will be reinforced with precast or cast-in-place concrete linings.



Each disposal container, or cask, will hold 21 or 44 fuel assemblies. Each cask contains enough plutonium to make at least 20 nuclear bombs.

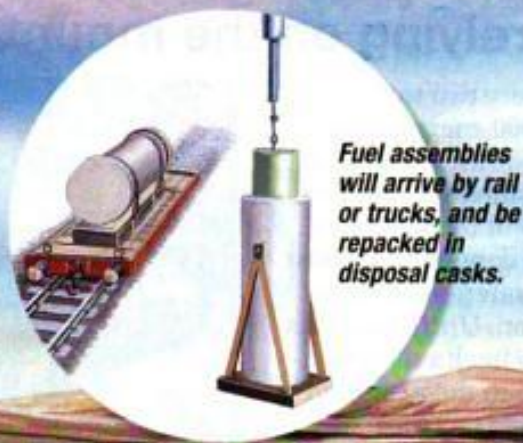


Radiation-shielded trains will move the casks into the drifts. Note the movable airlock, shown open (though it's normally closed), on the right.



Automated inspection machines may be used to monitor for radiation leaking from the casks.

PERIL



Before the repository is abandoned, all surface structures, including ventilating fans, will be removed.



A mine not far from Las Vegas is about to become the most radioactive place on Earth.

BY JIM WILSON

► Nuclear waste is hot,

physically and politically. And there is no place where you can feel the heat more than at Yucca Mountain, Nev. The federal government is preparing to make this hauntingly beautiful patch of desert 100 miles northwest of Las Vegas the most radioactive place on Earth. Beginning as early as 2010 a network of tunnels will be dug and simultaneously loaded with the most radioactive waste from the 100 or so nuclear reactors that supply about 20% of the nation's electricity.

ENERGY

Building a massive mine to store nuclear waste wasn't in anyone's original game plan. At the dawn of the nuclear age engineers saw the "spent fuel" that came out of reactors as potentially more valuable than the slightly enriched uranium dioxide "fresh fuel" that went in. Nuclear fission does more than make the steam that spins electric generators. A portion of the uranium fuel undergoes a transformation, yielding a cornucopia of radioactive elements. The most troubling of these is plutonium-239, which can be chemically separated and then used to make fuel for other types of power reactors and nuclear bombs.

As the concentration of these newly created elements increases in the fuel, the thermal efficiency of the reac-

What the United States views as nuclear waste, some countries consider nuclear fuel. After all the waste casks have been placed, but before the repository is closed, the spent fuel could still be removed and shipped to a reprocessing plant. If the waste stays put, a fence, warning signs and files in government archives would be the only indications of the vast mining operation.

Technology Watch

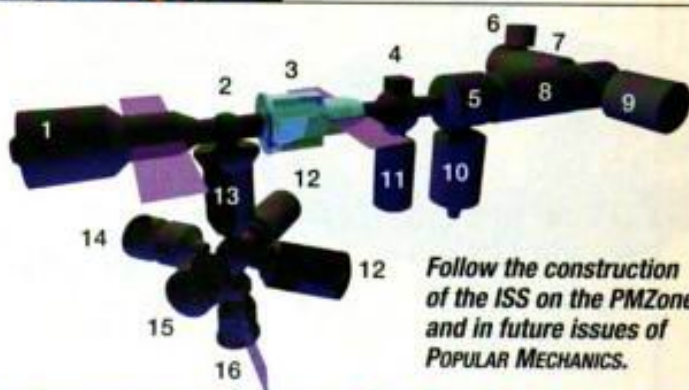


International Space Station Takes Shape

The most complex construction project ever attempted has begun with the joining of the first two elements of the international space station (ISS). Over the next five years, 44 shuttle missions and Russian launches and 1000 hours of space walks will take place as astronauts assemble about 100 elements into a permanent orbiting scientific lab.

The Russian-built *Zarya* (labeled "3" on the diagram below), which is sometimes referred to as a space tug, will provide power and propulsion, and act as a temporary docking port. The first U.S. component in orbit, *Unity* (5), is the connection point for the U.S. laboratory (8) and crew habitat (10).

A truly international effort, the 16-nation, 900,000-pound ISS will include Japanese (6 and 7) and European Space Agency (9) laboratories. Mating adapters (2 and 4)



Follow the construction of the ISS on the PMZone and in future issues of POPULAR MECHANICS.

will attach the Russian service (1) and docking (11,13 and 15) modules, as well as research (12) and life support modules (14), and provide for Soyuz spacecraft (16) docking.

"None of it's easy, but if it was easy, it wouldn't be worth doing," says Don Pallesen, a spokesman for NASA's Johnson Space Center.

Technology Watch

Aviation • Computers • Energy
Environment • Medicine • Military
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21st Century Sky Trooper

America's next generation of combat helicopters will have more in common with vertical-takeoff jets than with whirlybirds.

The rear, or canard-positioned, wing of the experimental Dragonfly, shown above, will enable the aircraft to make optimal use of the exhaust from a conventional turbofan engine.

During takeoffs, landings and vertical flight, a

diverter valve will direct the jet's exhaust to the rotor.

As forward movement produces more lift, the exhaust will be progressively diverted to the rear. When the rotor locks, all

thrust will be diverted aft.

"An operational canard rotor wing unmanned aerial vehicle would be able to take off and land in confined areas without a launch or recovery sys-

tem, rapidly transition to and from a fixed-wing mode, and fly at speeds in excess of 375 knots," says Larry Birkelbaw, who is managing the project for its sponsor, the Defense Advanced Research Projects Agency.

The Boeing Phantom Works, which is building an unmanned version, says the first demonstration flight will take place within two years. The Marines are eyeing full-size Dragonflies as escorts for MV-22 Osprey troop carriers, for development early in the next century.



April Highlights

Improved Sky Hook—New medium-duty helicopter makes an impressive first flight.

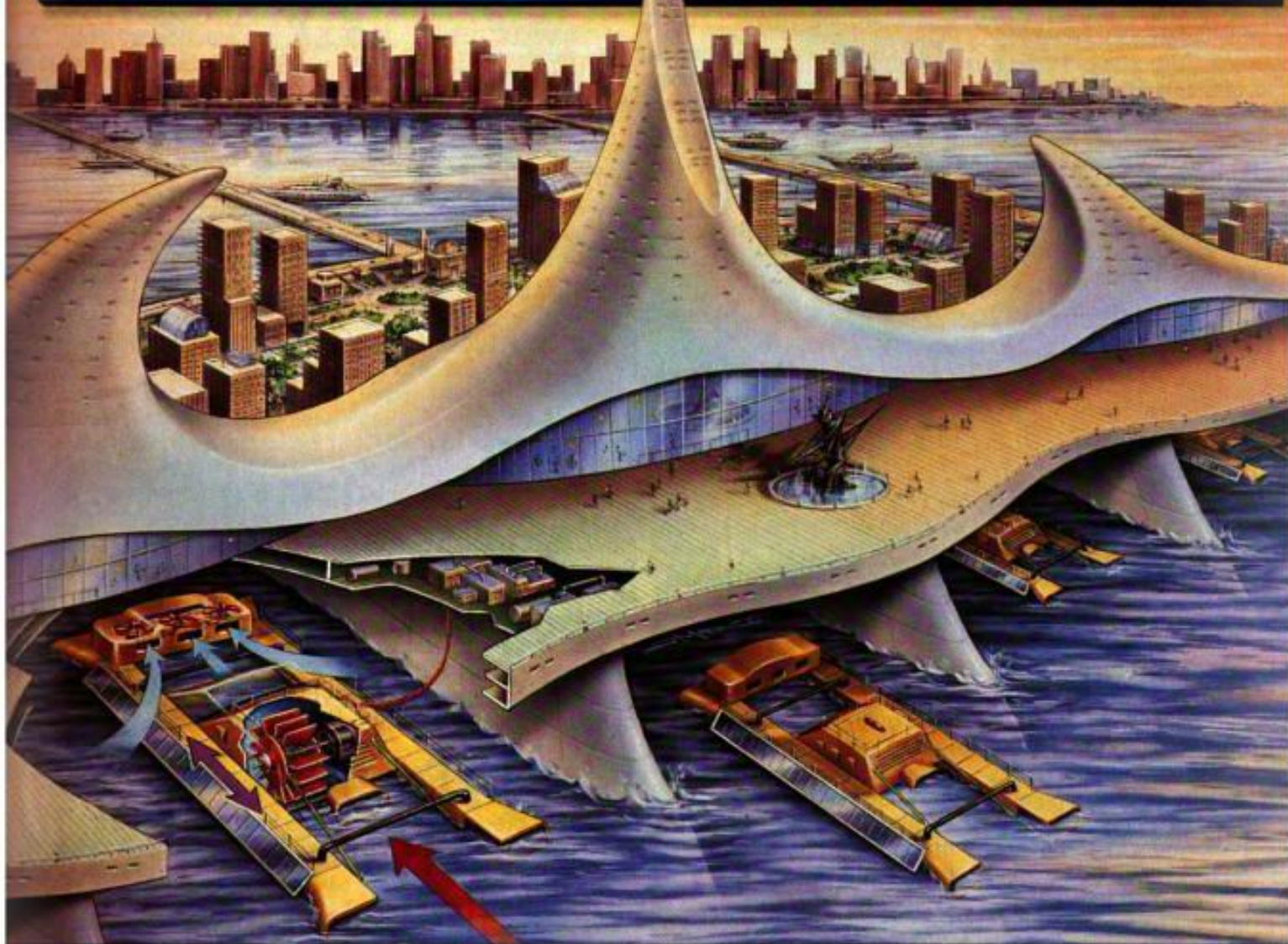
■ **Battery Saver**—New chips that run on as little as 1 volt will shrink cellphones even more.

■ **Easy Rider**—How a bet, spare parts, a salad bowl and \$15 built a 1500-speed bicycle.

Editor: Jim Wilson
Reporters: Stefano Coledan,
Steve Ditlea, Sandra Erwin,
Scott Gourley, Steve Shimek,
Andy Turnbull.

Technology Watch

Aviation • Computers • Energy
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Floating City Protects Shore

Atlantis may rise. Not from the mythical deep, but near ocean-front communities that need erosion protection and inexpensive power.

The Atlantis plan envisions creating recreation-based communities, such as the casino-marina shown above. While visitors played, the

mini-city would be hard at work taming the ocean's fury and generating low-cost power.

This work would be

done by barges called Merrimacks. Anchored to the seabed and riding just below the mini-city, they would blunt the force of

the waves by directing water through a specially designed raceway leading to a turbine that spins a generator.

In tests performed at the New Jersey Institute of Technology, an 8 x 20-ft. model generated 460 watts. Atlantis developer U.S. Myriad-Technologies (USMT) of West Caldwell, N.J., (888-227-2296) concludes that a community could derive enough power to be self-sufficient.

USMT says that several shore-front towns from as far away as Holland and Australia have expressed interest in its idea.



May Highlights

Record Breaker—Carbon composite turboprop sets speed record for climb.

■ **Bionic Boots**—Inspired by a kangaroo, the next sporting craze springs up in England.

■ **Internet Cooking**—Appliance maker merges a Net-ready computer with the microwave oven.

Editor: Jim Wilson
Reporters: Stefano Coledan,
Ken Cottrill, Steve Ditlea,
Mike Filon, Cliff Gromer,
Barry Rosenberg.

SHRINKING MICROMACHINES

A new generation of tools will make molecule-size machines a reality.

BY JIM WILSON, Science/Technology Editor

Some of the best minds in science believe that in the not-too-distant future, a friendly fog will settle over the planet. Unlike its traffic-

snarling, airport-closing twin, this "utility fog" will be downright helpful. It will put roofs over homeless heads, clothes on bare backs and food in empty stomachs. It will have the power to transform the most desolate village into a Garden of Eden, with widescreen TVs and cappuccino machines for all.

The brainchild of J. Storrs Hall, a Rutgers University computer scientist, utility fog embodies one of the more dramatic promises of molecular nanotechnology, the next step in downsizing the machine age. Like its natural counterpart, utility fog would be comprised mostly of air. But instead of this air being filled with trillions of water droplets, it would carry trillions of germ-size nanomachines called "foglets." These general-purpose robots—each with the horsepower of a mainframe

The good fortune of nanodevice is that it is the diameter of a carbon nanotube, precisely the right size to act as a highway to roll down its core.

SHRINKING MICROMACHINES

computer—would work collectively to fulfill your heart's desires.

No one expects a cloud of these magical machines to come billowing out of anyone's laboratory tomorrow. But a recent landmark suggests that the bold promises of nanotechnology may not be as far-fetched as they seem. In April, Zyvex, the world's first company devoted exclusively to developing the elusive assembler—a device that builds with individual atoms—went into business in Richardson, Texas. "Zyvex's goal is to build one of the key pieces of molecular nanotechnology, the assembler," Jim Von Ehr, its founder, told **POPULAR MECHANICS**.

Zyvex's first machine won't look anything at all like the invisible robots envisioned by K. Eric Drexler, who conceived the idea for nanotechnology and then wrote the textbook on how to build machines that could assemble anything, one atom at a time. In fact, Von Ehr says his first machine might even turn out to be the size of a desktop computer or even a compact car.



Virtual reality systems created at the University of North Carolina at Chapel Hill enable chemists to examine the structure of a molecule with a finger-guided probe.

At this stage of the game, size—what nanotechnology is all about—oddly doesn't seem to matter. What is important, says Von Ehr, is that his assembler will function the same way as those that may one day be used in foglets. "The assembler will probably perform its task by doing mechanochemistry, which is a chemical reaction helped over its normal

reaction barriers by mechanical force," Von Ehr says. Essentially, this means whacking the atoms in place. "Another possibility is positional electrochemistry, which overcomes the reaction barriers by careful use of electrical charge." In other words, persuading them to move with the help of a very, very small cattle prod.

In the 20 years since Drexler introduced the concept of nanotechnology, developers have learned to make the task of moving individual atoms more and more routine. Three microscopes (see chart on opposite page) currently comprise the basic tools of the trade. A scanning tunneling microscope (STM) places an atomically sharp point with a small voltage potential near a sample material and, by measuring the number of electrons that jump across the gap—physicists use the term "tunneling"—creates an accurate representation of the structure. Atoms then can be moved by electrical repulsion or attraction. An atomic force microscope (AFM) is a variation on the STM theme. The small upward and downward movements of the tip needed to maintain a constant force of contact on a surface is used to produce images. A scanning probe microscope (SPM) operating in a "tapping mode" can record variations of friction as a tip is dragged across a sample. It can also nudge individual atoms from place to place.

These devices can all image and move materials, but in steps that are less than the diameter of an atom. As a result, they're very slow. Cornell University professor of electrical engineering Noel C. MacDonald believes he and his graduate students have found a way to step on the gas.

Microscopes currently used in nanotechnology research use piezoelectric

Downsizing The Factory

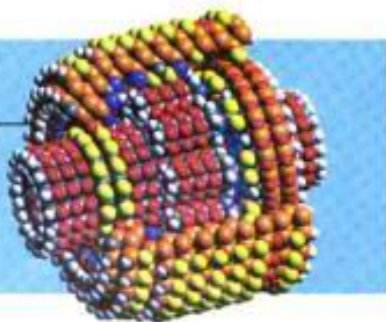
Minimachines

These consist of billions of atoms. Finished parts, shown inside a bent paper clip, are measured in millimeters.



Micromachines

These also consist of billions of atoms. The finished parts shown here alongside coagulated blood cells (left and lower right) and a grain of pollen (center) are measured in micrometers.



Nanomachines

Their parts will consist of hundreds of atoms. Complete, computer-controlled machines will be measured in nanometers.



Quantum Machines

These will consist of stretched parts of a single atom and will be measured in Angstroms.

drive systems about as big as your thumb. Using fabrication techniques developed for the semiconductor manufacturing industry, MacDonald has reduced these drives to about the diameter of a human hair.

"As these devices are scaled down, we can make them scan much faster," MacDonald says. "At the order of a thousand to a million cycles per second. That's not 100 cycles, like conventional STMs. You can move things around in a microsecond that previously took minutes."

It is important to understand that AFMs, SPMs and STMs could not actually build the foglets that float in the utility fog. These existing instruments will build the first generation of assemblers. The machines in the utility fog would likely be built by still smaller microscopic assemblers several generations removed.

Regardless of their size, assemblers, and most likely their parent machines, will be made of carbon. For one thing, there is plenty of raw material available, including the carbon dioxide that humans and fossil-fuel-burning machines produce. For another, the element has some very unique self-assembling properties.

Carbon atoms can arrange themselves in different forms. Just about everyone knows that coal and diamonds are made of the same stuff. So too is an even more enduring form of carbon: carbon nanotubes. In July, Rice University researchers announced they had successfully produced defect-free carbon nanotubes in useful quantities.

Resembling bundles of long drinking straws, nanotubes are related to the buckyball, a carbon fullerene cage that is shaped like a soccer ball. It was discovered at Rice in 1985. "The single-wall nanotube is to the family of tubes what the buckyball is to the family of fullerene cages," says Richard Smalley of the Center for Nanoscale Science and Technology at Rice University, who shared a Nobel Prize for his work on fullerenes.

Smalley is enthusiastic about the

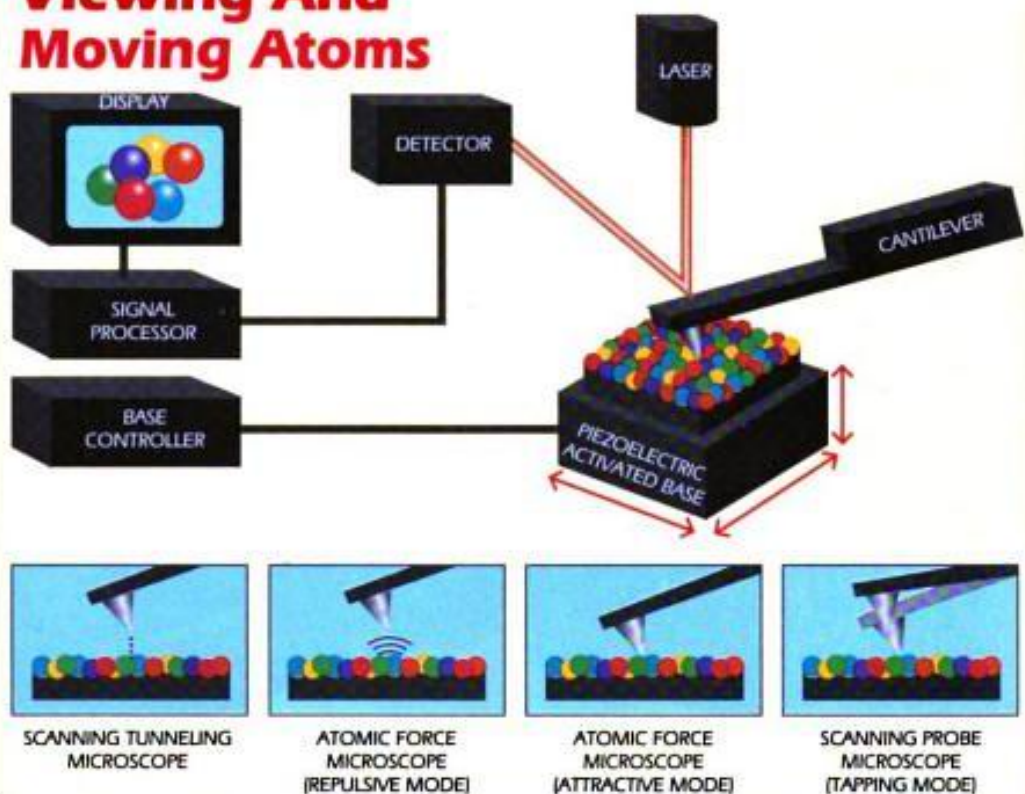
future. "If we can understand why these nanotubes are made, perhaps we can control the growth and make them grow forever," he says. But even if Smalley's nanotubes do not grow another millionth of an inch, they will have still made a lasting contribution. As soon as they first became available, nanotech researchers began fitting them on the tips of their SPMs to make the tips more rugged. "You can bang these things around all day," says Ralph C. Merkle, a research scientist at Xerox Palo Alto Research Center. "I think scanning probe techniques offer the most promise,



Most micromachines are made with etching.

ternet-based supercomputer with a world speed record goal of 10 trillion operations per second. Individuals

Viewing And Moving Atoms



since they let us work down to the molecular level."

And if molecule-size machines weren't small enough, consider this. Researchers at several laboratories here and in Europe believe it may be possible to someday build a quantum machine, with parts made of what is *inside* a single atom.

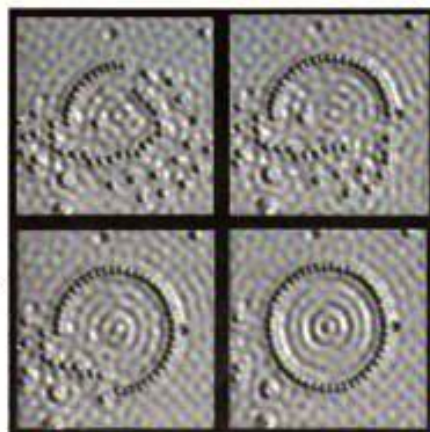
Progress in developing on-board computers to control these ultra-small devices is getting a boost from PC owners worldwide. A project called the Dream Team To Design And Build The First Nanocomputer has developed an In-

who wish to help the nanotechnology effort can arrange to contribute unused time on the CPUs of their computers. A special screen saver will tell them how many cycles they have contributed.

So, how long will it be before nanotechnology delivers on its promise? "There is a fair amount of debate," says Merkle. "It is plausible that in the next century, we will be developing this technology. There aren't any fundamental barriers. On the other hand, it might take multiple decades."

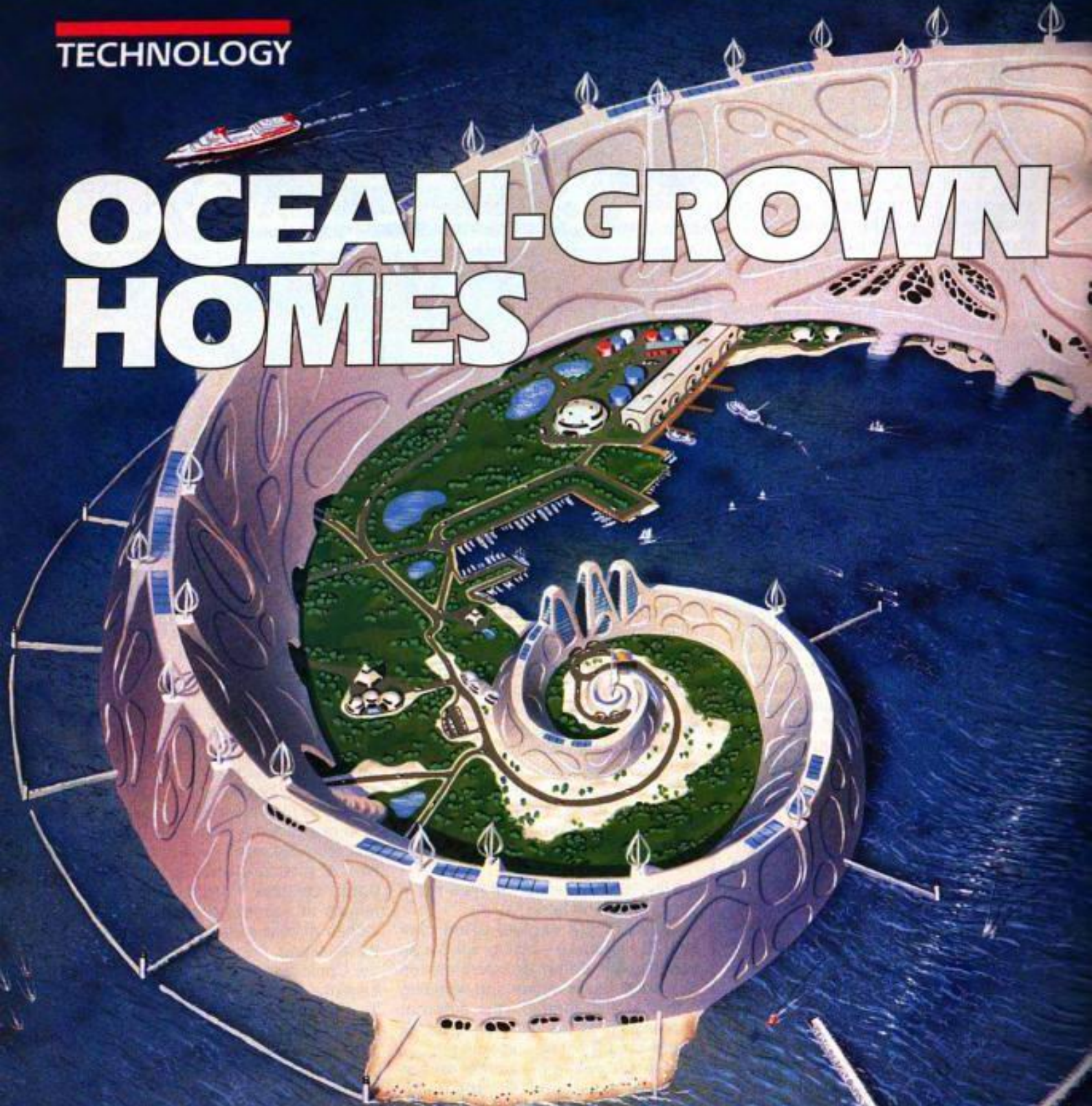
"The debate has shifted from 'Will it happen?' to 'When will it happen?'" says Chris Peterson, executive director of the Foresight Conference, which is the world's largest scientific and engineering meeting devoted exclusively to nanotechnology. "I feel there is no question it will happen in our lifetime. For me, this means the next three decades."

PM



Nanomachines are made atom by atom.

OCEAN-GROWN HOMES



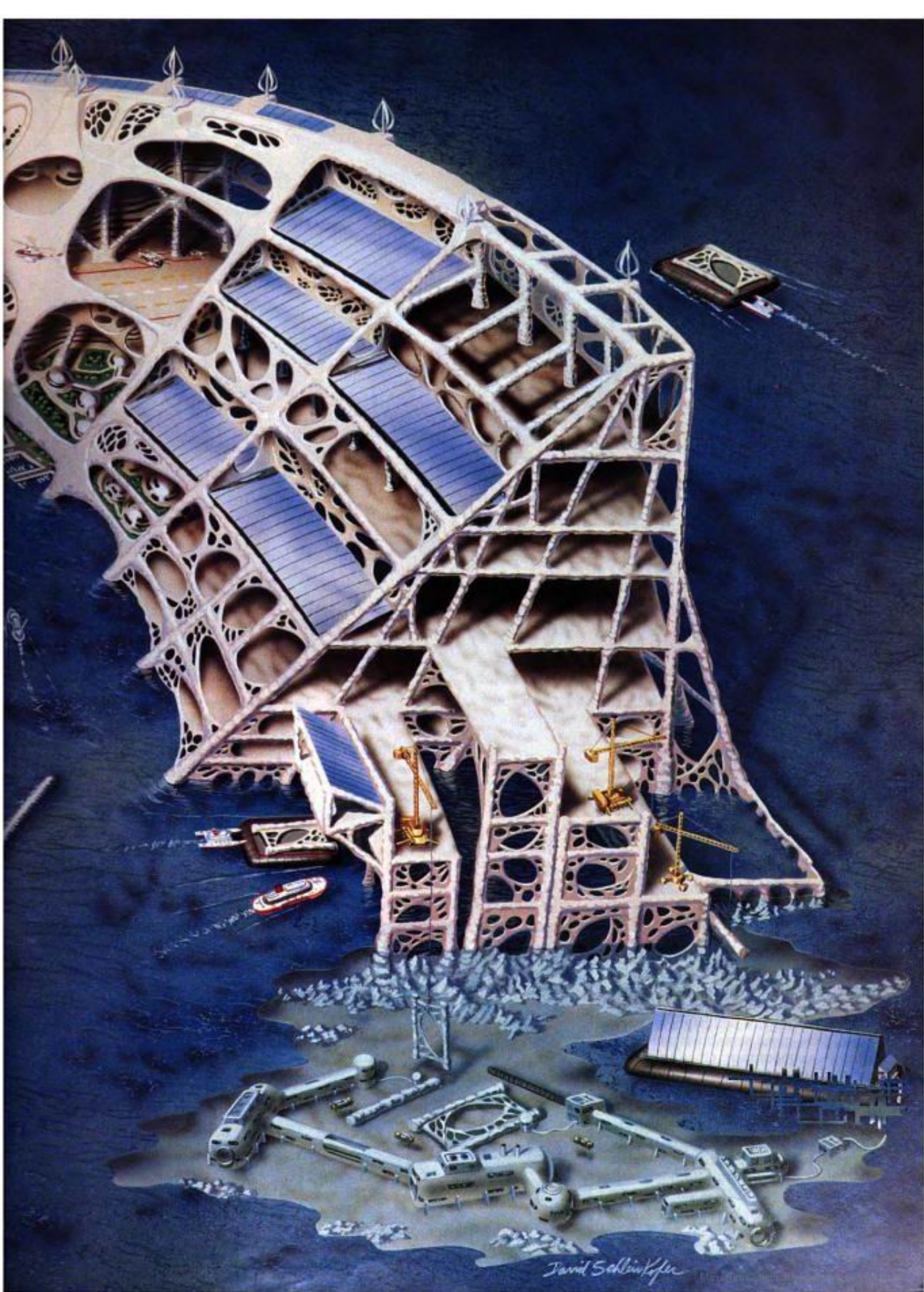
The seas absorb carbon dioxide from the air. Wolf Hilbertz wants to use it to build low-cost housing.

BY ANDY TURNBULL; PM Illustration by David Schleinkofer

● A cargo ship drops anchor in choppy water 300 miles off the coast of North Africa. With practiced efficiency, its crew deploys the ship's crane and begins hauling house-size wire frames and reels of thick electrical cable from the hold. As quickly as this cargo appears topside, it is flung overboard, disappearing into the gray, swirling

sea. When the decks are finally clear, the crew begins assembling floating solar panels that look like adult-size tinkertoys. The ship's engines rumble as the first of these ungainly structures is hoisted skyward and carefully deposited alongside. The activity continues until they form a vast spiral that dips below the horizon as the ship

Once completed, Autopia Ampere would become entirely self-sufficient. Wind and sea currents would provide energy. Marine life, both wild and cultivated, would furnish food. The "mineral accretion" process from which the island was built would be used to create building materials for global export. The underwater manufacturing process itself would help to control the buildup of CO₂, which is a greenhouse gas.





Coral (right) inspired Hilbertz's ocean-derived building process, which forms limestone on wire forms (below).



steams away. Five years later, a luxury cruise liner drops anchor at precisely the same place. Instead of finding bobbing rafts, the passengers lining its decks see the thriving island of Autopia Ampere. With a population of 50,000, it is the newest destination for "eco-tourists," an honor befitting its stature as the first city to rise from the sea.

All of this is the dream of German architect Wolf Hilbertz. It represents the ultimate application of the "mineral accretion" building technology he pioneered when he was an associate professor of architecture at the University of Texas. Simply put, Hilbertz has found a way to use sunlight to turn the minerals in seawater into limestone.

Autopia Ampere will begin as a series of wire-mesh armatures anchored atop a sea mountain. Once in place, they will be connected to a supply of low-voltage direct current produced by solar panels. Over time, electrochemical reactions will draw minerals from the sea to the armatures, creating walls of calcium carbonate, which is what us landlubbers commonly call limestone. (See illustration on page 57.) In much the same way that a household sponge absorbs water, the oceans absorb CO_2 . By removing carbon-containing compounds from the

oceans, the mineral accretion process would help reduce the buildup of CO_2 , which is a greenhouse gas.

The idea works in practice as well as theory. Hilbertz began modestly enough, by growing a coating of limestone on wooden piles wrapped in chicken wire at 30 piers on the coasts of Texas, Louisiana and California. He is now a visiting professor of architecture at the Hochschule fur Kunst in Bremen, Germany, and an adjunct professor at McGill University

in Montreal, Canada, and he has moved on to a larger project. He invited **POPULAR MECHANICS** to see a sample of his handiwork that is using the same technology to build artificial reefs off Jamaica.

Working with the Negril Coral Reef Preservation Society, Hilbertz now has five experimental reefs growing around the island. Three of the experiments use power from the shore. A fourth uses a "sacrificial anode," in effect making a wet-cell battery from



Hilbertz constructs a mineral-collecting wire form.

nearby seawater. The fifth runs on solar power.

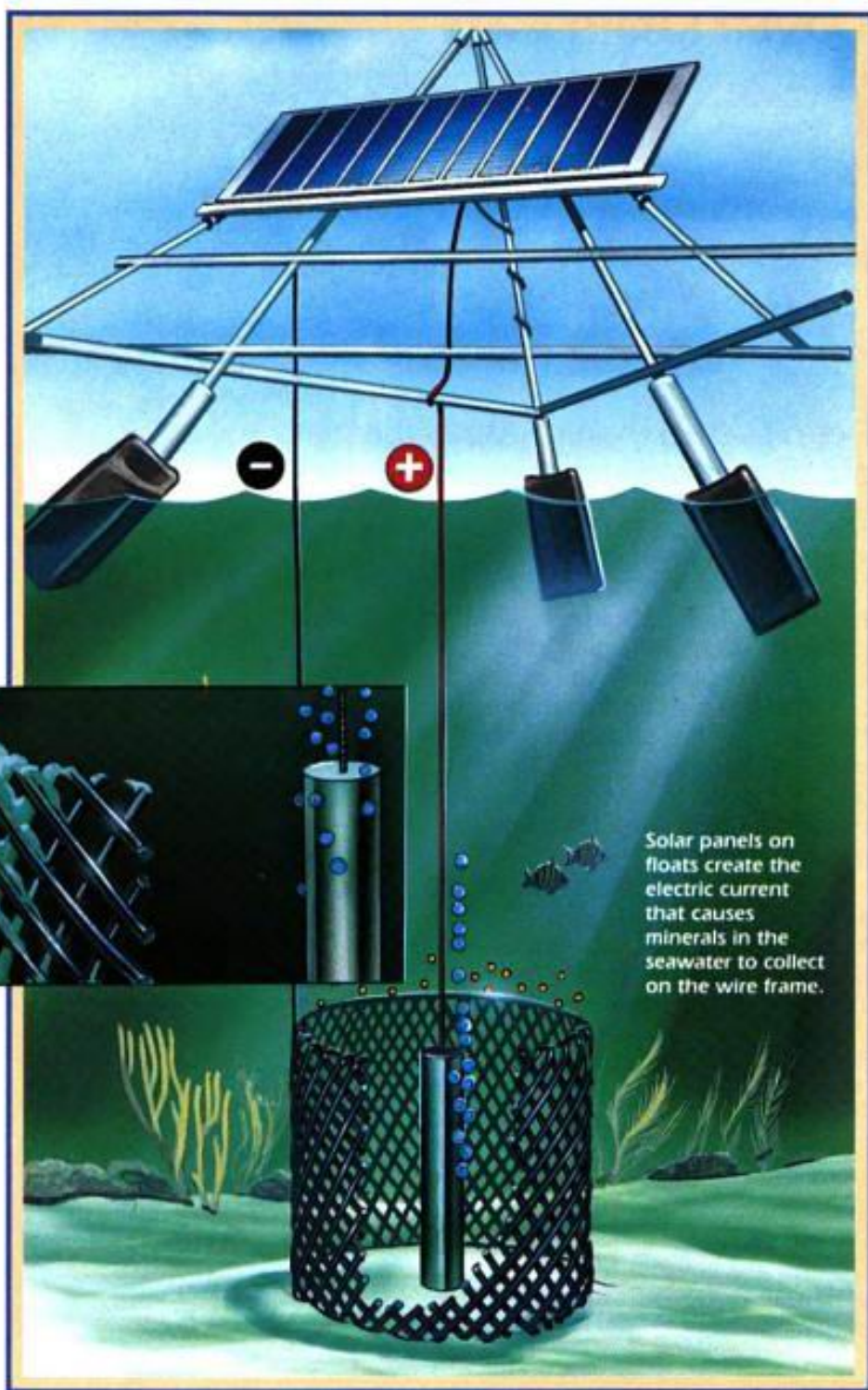
As a step toward his ultimate ocean-grown city, Hilbertz has planned to grow a self-sustaining island city on Seamount Ampere, which is situated about halfway between the Madeira Islands and the tip of Portugal. If constructed, it will extend 50 ft. down to the bottom of the Atlantic in that spot. Besides shallow water, the site offers good fishing, a dependable ocean current, and polymetallic nodules on the ocean floor that contain copper, cobalt, manganese, nickel and iron.

A huge limestone dam will surround the city, Hilbertz says, and building components will be grown in the sea, as shown in the illustration (right). Solar and wind generators will furnish power. So too will a thermal energy conversion system that will extract power from temperature differences among different ocean currents.

One of the cornerstones of the new city's economy would be "limestone farming." The mineral accretion technique that has built reefs in the Caribbean and that could one day build marine cities could also make building components for use on land. Using appropriately shaped wire forms, the minerals deposited from seawater could grow building blocks, wall panels or complete building components just like those that would build a sea-born city, but for use on dry land.

Hilbertz envisions these products being lifted directly out of the sea into barges and ships, which could deliver them to seaports around the world. A limestone farm in the Caribbean could efficiently ship the building materials to coastal areas of North and South America, Europe and Africa, to inland North American ports on the St. Lawrence Seaway and Mississippi River systems, to most of Central Europe via the Rhine, Rhone and Danube rivers and to most of the Amazon basin in Brazil. A farm in the South Pacific could service the west coast of North and South America, and booming Pacific Rim countries.

Hilbertz also envisions others of his cities becoming centers for an under-sea mining industry. The seafloor is believed to be littered with metal- and mineral-rich nodules, from which refiners in a city will produce pure metals. The fact that metals refining is an energy-intensive activity isn't the least bit daunting. He enthusiastically describes a plan in which the sea would "grow" limestone conduits that would tap deep, slow-moving ocean currents and guide them through the blades of giant hydroelectric plants.



Whatever Hilbertz's cities manufactured, their occupants would dine on the bounty of the sea. Wild fish would be guided into nets, and domestic fish would be raised in pens, along with cultured abalone, sea urchins, oysters, mussels and other shellfish. Useful seaweeds will be cultured, and more common vegetables would be grown in hydroponic chambers.

The fact that ocean-grown cities could stand on their own economically and become independent and self-governing entities poses what Hilbertz believes to be one of the biggest barriers to their creation. He says there is no legal precedent regarding national ownership of a newly formed island that is beyond a

nation's territorial waters.

He plans to face this issue head-on with an experiment on Skerki Bank, in the Mediterranean Sea. The bank consists of a few-hundred square yards of knee-deep water between Tunisia and Sicily. It's in international waters, but within the area both Italy and Tunisia claim as an "Exclusive Economic Zone."

Hilbertz hopes to start growing an island there before the end of the year. "We'll establish our presence there and stake a claim, and see what happens. If anyone challenges us, we have lawyers ready to argue our case. We've had so many legal opinions that we decided just to go ahead and see what happens," he says.

FM

TECH UPDATE

News Of Tomorrow's Technology Today



Control surfaces on the front delta wing make the UCAV highly maneuverable.

First Look At Next-Generation Stealth Fighters

EL SEGUNDO, CA—The only thing that's missing from Northrop Grumman's proposed 21st-century jet fighter is an ejection seat for the pilot.

"Emerging use of real-time datalinks between controllers and a weapons system will allow vehicles like the uninhabited combat air vehicle (UCAV) to penetrate and attack highly defended target areas without placing air crews at risk," says Greg Zwernemann, manager of advanced uninhabited concepts for the company's military aircraft systems division.

Looking like something out of a science-fiction movie, the 27-ft. gull-wing UCAV is intended for the most dangerous types of missions: air defense suppression and deep strikes. Its base-to-target range will be comparable to an F-16 at about 800 miles.

A typical flight would begin with the UCAV using GPS to navigate toward its target. Its tailless design presents a small radar cross section, thus improving its chances of penetrating enemy airspace at subsonic speeds.

Once over hostile terrain, the craft would rely on stealth technology originally developed for the B-2 bomber to avoid radar detection. A constantly up-

dated computerized flight plan would help the UCAV evade air defenses. Once the plane is near the target, a pilot on the ground would remotely verify targets and launch weapons. The company will not specify the UCAV's payload capacity, other than to say it will carry a mix of 250-, 500- and 1000-pound precision-guided munitions. After it released its bombs, the UCAV would be able to fly home unassisted.

Because the planes would be smaller and wouldn't require a pilot life-support system, industry insiders estimate they would cost about \$12 million each, which is less than half as much as a conventional F-16.

Although the Pentagon has not officially announced it is interested in buying unmanned jet fighters, the company's efforts have already progressed as far as wind-tunnel testing.



Highlights This Month

- **Power Shift**—World's largest hydrogenerator repair.
- **Paris Air Show**—Highlights from world's biggest exhibit.
- **Nuclear Alert**—Accidents plague Japanese atom plants.
- **Before Leonardo**—Working models of early wonders.
- **Mostly Air**—Smaller cells create ultradense plastics.
- **Life Preserver**—Sea monkey protein aids immortality.
- **Teflon Plants**—Nonstick coating comes to dress clothes.
- **Cheap Chills**—Old ideas cut refrigerator energy costs.

Editor/Writer: Jim Wilson
Reporters: Chris Dean, Mike Fillon, Bill Garvey,
Scott Gourley, Cliff Gromer, Barry Rosenberg

camps. The fact the Nazis had technology that American engineers could not duplicate was deemed too harsh a message for a nation that had gone to war for a higher moral purpose.

Probing further into the fate of the Horten brothers, PM learned that just prior to their capture they had been working on the design for a new generation of circular-shaped vertical-takeoff aircraft, with specifications much like those described in the Silver Bug re-

port. Other records indicate that after the war, models of the Horten's designs—possibly constructed by the brothers themselves—were tested in the wind tunnel at Wright Field, now Wright-Patterson Air Force Base. This is the same base to which the wreckage of the Roswell crash was finally transported.

The Air Force acknowledges the Germans were working on a flying-disc craft, but says it was inherently unstable. Officials point to the failed Avro flying car built for the Army and a deteriorating plywood Horten wing, both on display in museums.

Declassified records obtained by PM in the course of its investigation suggest that these marginally performing craft were, in fact, shells intended to disguise the existence of more formidable flying machines. One of the most potent of these flying discs was developed under a secret program called Project Pye Wacket. Its objective was to design a 5-ft.-dia. liquid-fueled missile launch platform to protect U.S. bombers penetrating Soviet airspace.

In the end, the military would select conventionally shaped planes and missiles. As for the Horten flying disc

that the Reich had hoped would turn the tide of battle, patent rights to a remarkably similar craft configured to carry "passengers" would be assigned to the Lockheed aircraft company. A cutaway diagram of this unusual craft appears on the top of this page.

Despite this information, the possibility that the object that crashed at Roswell was in fact one of the Horten brothers' creations misses the mark on two important details. The craft that Kaufmann claims to have helped recover was not round, but as his sketches showed, a lifting body. Also, he claims there was no fire damage, a virtual impossibility in the crash of a jet-powered aircraft.

A Japanese UFO

As our investigation neared its close, PM was alerted to a forthcoming release of documents that may fill in these two missing pieces of the Roswell puzzle. They may also explain two other curiosities: the presence of the crisscrossed radar-deflecting pattern on the bottom of the Roswell craft, and—to the consternation of those who seek an unearthly explanation for Roswell—the origin of the "dead aliens" who have so often been described as having Oriental features.

PM has been told that the documents scheduled for future release will tell of a Japanese counterpart to Operation Paperclip. One of its purposes was to determine if the Japanese had constructed a suicide-piloted version of the Fugo incendiary bomb.

During the Second World War, the Japanese launched these unmanned high-altitude balloons in the hope that they would land in the Pacific Northwest, explode, ignite forest fires and thereby deprive the war effort of needed lumber. The effort was an obvious failure. The Japanese may have attempted to build a second generation of Fugos that could be guided to targets by suicidal pilots.

PM suspects the craft that crashed at Roswell will eventually be identified as either a U.S. attempt to re-engineer a second-generation Fugo, or a hybrid craft which uses both Fugo lifting technology and a Horten-inspired lifting body. In either case, Japanese engineers and pilots brought to the U.S. after the war to work on the project could have been the dead "alien" bodies recovered at the crash site. Also, equipped with a rudimentary radar-deflecting underside, such a balloon could have reached stratospheric altitudes as it traveled over Western Europe and been well above the range of then-existing MiG fighters and missiles even if it had been detected. It could have carried out both photo reconnaissance and air sampling experiments—similar to those of the Mogul balloon—before gliding back to Earth in friendly territory.

Fifty years after the fact, the questions about Roswell still ring loud and clear. Our investigation leads us to believe the explanations that require an extraterrestrial presence, while possible, are nevertheless highly implausible. We're putting our money on a flying disc labeled "Made In Japan." **PM**

Lockheed was assigned patent rights for a passenger UFO. Its design was among several developed by the military and aerospace companies.

TECH UPDATE

News Of Tomorrow's Technology Today



PM ILLUSTRATION BY PAUL DIMARE

200-mph Trees Bomb Away At Greenhouse Effect

CAMBRIDGE, MA—The solution to global warming may be to bomb the planet—with trees.

Scientists generally agree that burning carbon-based fuels could release so much carbon dioxide that the Earth's atmosphere might begin to behave like a greenhouse, causing temperatures—and possibly sea levels—to rise.

There is less agreement on how to solve the problem. More fuel-efficient engines help, but they can't offset increased coal and oil demands imposed by the world's growing population.

Moshe Alamaro believes the answer is to enlist military technology to replace the forests that flourished before the Industrial Revolution and household wood burning began consuming trees faster than they could grow back. The key to his plan is an

aerodynamic tree-planting cone he developed while working toward a doctorate in mechanical engineering at Massachusetts Institute of Technology. Constructed of a starchy and biodegradable material, the cones are strong enough to sustain the 200-mph impact of striking the Earth after being dropped from a military transport.

Alamaro hopes to plant the trees in remote, uninhabited areas. Electric-

Surveillance equipment aboard airships would determine when it was safe to drop trees and probes that monitor soil.

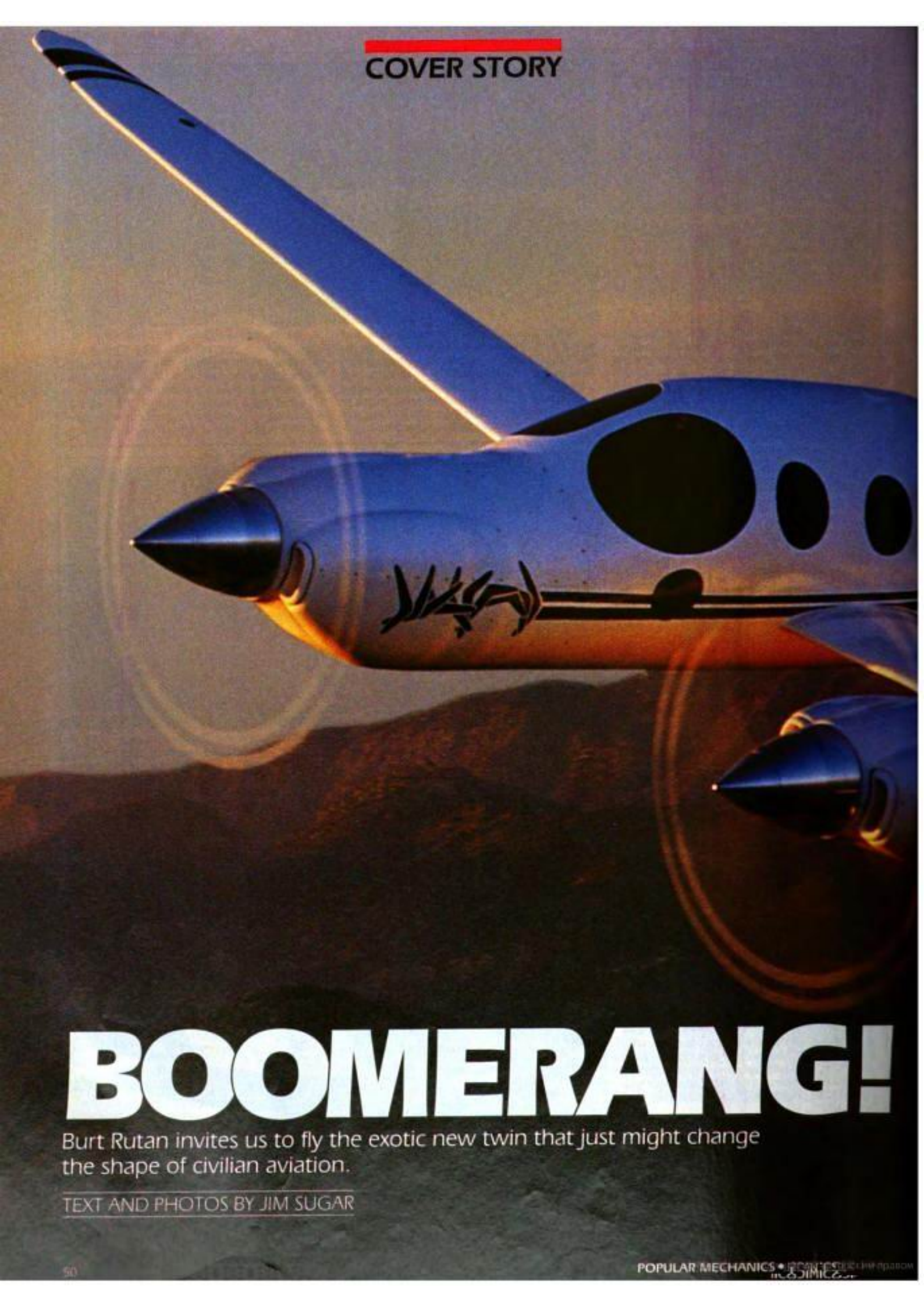
power companies would pay him with money saved from carbon-dioxide-capture tax credits, which are now being considered in several countries.

"Even if theories about global warming turn out to be wrong," Alamaro says, "replanting forests is still good for the planet."

Highlights This Month

- **Robotics Debut**—New lab to build intelligent machines.
- **Blind-Spot Radar**—Takes aim at lane-change accidents.
- **First-Class Cargo**—Newest 767 hauls livestock in style.
- **Exotic Rocket**—Inside-out engine will power the X-33.
- **Weather-Safe Wings**—Camera spots plane ice hazards.
- **International Inventors**—Ideas from 300 countries.
- **New Air Conditioning Cycle**—Cool, dry air gets cheap.

Editor/Writer: Jim Wilson
Reporters: Louis M. Brill, Ken Cottrill, Mike Fillon,
Joshua Shapiro



COVER STORY

BOOMERANG!

Burt Rutan invites us to fly the exotic new twin that just might change the shape of civilian aviation.

TEXT AND PHOTOS BY JIM SUGAR



For Burt Rutan, wife Tonya (inside cockpit) and brother Dick, the *Boomerang* is a showcase of ideas conceived over 25 years of building flying machines.

right when Rutan invited us to take the controls of the *Boomerang* during a series of shakedown flights before the plane's departure for the Experimental Aircraft Association's 1996 fly-in held in Oshkosh, Wisconsin.

"This is the most significant plane that I've ever done," Rutan said as he rolled the unique *Boomerang* out of his company's hangar here in Mojave, California.

The *Boomerang* is more than an eye popper. It solves the chronic safety and cost problems that have discouraged private pilots from moving up to light twins. In conventionally designed twins, an engine is mounted on the leading edge of each wing, with the fuselage in the middle. As scores of twin engines have proved, this design works just fine. Provided, of course, that both props keep spinning. When one engine loses power or quits on takeoff, thus producing asymmetric thrust, disaster often follows. This is due to inadequate control at low speeds or inadequate climb on one engine.

"The engine-out safety of most twins is so bad that even though they provide engine-failure redundancy, they kill more people per mile than singles," says Rutan. Only Cessna's Skymaster and an earlier Rutan de-

sign, the Defiant, avoid the low-speed control problem, by using an inline push-pull design.

With the *Boomerang*, Rutan tried an entirely different approach. He has placed a 210-hp engine on the nose of the fuselage and a smaller 200-hp engine on a boom connected to the left wing, separating the two puller-prop tips by a scant 12 in. Positioning the engines so close together shifts the airplane's center of gravity 5 in. to the left of the fuselage. That means the *Boomerang* can fly nearly straight ahead on a single engine with almost no need to touch the rudders, regardless of which engine quits. And, also unlike other twins in its class, the *Boomerang* flies almost straight at all speeds with no tendency to roll or yaw. These very desirable flight characteristics derive from the *Boomerang*'s weird-looking asymmetry. The positions of the engines and wings cancel the normal aircraft's asymmetries caused by the similar rotation of left and right propellers.

The *Boomerang*'s all-composite construction, which is mostly graphite, helps to solve the cost problem by making the plane faster and more fuel-efficient. Rutan thinks it is fair to compare his *Boomerang* with a pres-

surized 6-seat Baron. "At 265 miles per hour, the *Boomerang* uses only 46% of the Baron's fuel," he says. At its maximum cruise speed of 304 mph, the *Boomerang* outruns the Baron by 40 mph while still burning 60% less fuel. And, says Rutan, the *Boomerang*'s range at economy cruise is more than 2300 miles, 60% farther than the Baron, even though the Baron carries more fuel.

Another fundamental design innovation is the Macintosh 5300C PowerBook. Running software written by Rutan's son Jeff, an engineer, the laptop provides GPS navigation plots and monitors engine and airframe performance from the first turn of the prop until the plane rolls to a stop after a flight. And if for any reason the PowerBook should fail, a set of miniaturized engine instruments permit adequate backup operation.

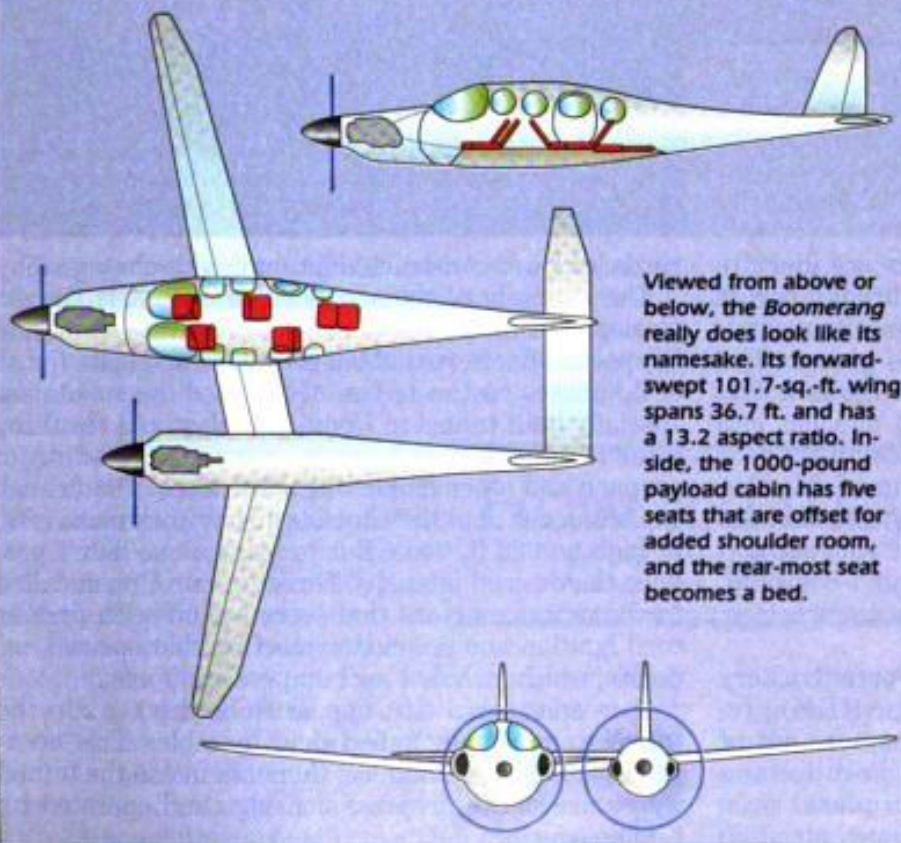
"With the *Boomerang*, I wanted to put many of the design ideas I've accumulated in the past 25 years into one plane," Rutan says. By using his own money and by building the plane with only the help of wife Tonya and friend Steve Losey, Rutan created a plane that is as much a personal statement as it is a practical flying machine.

On the day POPULAR MECHANICS arrived to take air-to-air photos of the *Boomerang*, a crew of eight gathered at 5 am in Rutan's office for a preflight briefing. At 6:30 am, we launched a chase plane, the *Boomerang*, a Defiant and a Long-Eze.



Boomerang gets its brains from a Macintosh PowerBook, which handles GPS navigation and monitors performance. Controls are mechanical pushrods in a manual flight control system. Offset seats (below) make for a roomier feel.

Inside The Boomerang



Viewed from above or below, the Boomerang really does look like its namesake. Its forward-swept 101.7-sq.-ft. wing spans 36.7 ft. and has a 13.2 aspect ratio. Inside, the 1000-pound payload cabin has five seats that are offset for added shoulder room, and the rear-most seat becomes a bed.

Twenty minutes later, waiting for sunrise, we watched Rutan's creations flying in tight right-echelon formation 10,000 ft. above the Mojave Desert. The sight of the day's first light dancing over the wings of these most imaginative aircraft produced a huge adrenaline rush.

By 8:30 am, the photo shoot was finished. When all the planes were back on the ground, Rutan prepared the software in the Boomerang's Macintosh computer. "I need to get some real work done," he said, inviting us along on what would be the Boomerang's sixth flight.

Simply climbing into the Boomerang is a unique experience. There is a rear door on the right side for passengers. The pilot and copilot enter through the right front windshield, which opens inward and slides aft. With the front window/door closed, the view is similar to the bubble cockpit of a Bell JetRanger helicopter.

Rutan's touches fill the cabin. A set of knee-level windows adds downward visibility, which is especially handy during taxi, takeoff and landing. Seats are staggered by several inches, creating an amazing amount of shoulder space. The Boomerang's most remarkable flying characteristic is its complete normality. And, just as Rutan has promised, the plane's unbalanced exterior makes for light, balanced control that quickly puts the pilot completely at ease in the cockpit. In fact, it handles more easily than a single-engine or a conventional twin.

With the Boomerang, Rutan has done more than solidify his already enviable place in aviation history. While there are no immediate plans to manufacture or sell licenses for its design, the ideas showcased in the Boomerang will undoubtedly improve the safety and economy of twin-engine flight in ways that just might open up a whole new chapter in civil aviation.

FM

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WILD BOOMERANG PLANE!

Burt Rutan's novel
design is the safest and
most fuel-efficient twin ever

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Hovercraft Takes Off Navy Uniform

FAREHAM, ENGLAND—The successful circumnavigation of the Baltic Sea by a British M-10 hovercraft during sea trials conducted by the Swedish and Finnish navies has inspired ABS Hovercraft to design a civilian version.

The proposed P-89 hovercraft would whisk as many as 90 passengers over choppy seas at 40 knots. The design borrows the powertrain and

control systems from the M-10, which has also proven its reliability in coast guard, police and rescue service.

Inside, the P-89 follows the layout of a jetliner. Passengers can get on and off quickly through wide fore and aft cabin doors, meaning faster in-port turnaround and more trips per day.

In the civilian version, the crew wheelhouse has been moved far for-

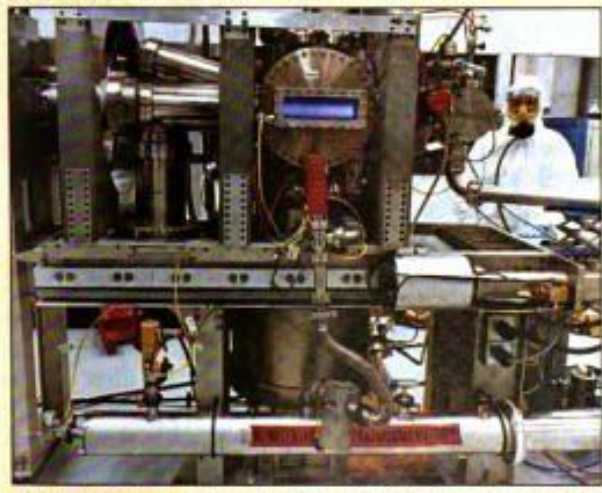
ward for maximum visibility. The cockpit has been simplified, so the P-89 can be operated by one person during the day. A radar operator would report to duty only at night.

If the P-89 concept catches on, the wave-skimming hovercraft could be an attractive alternative to ferry service on short runs.

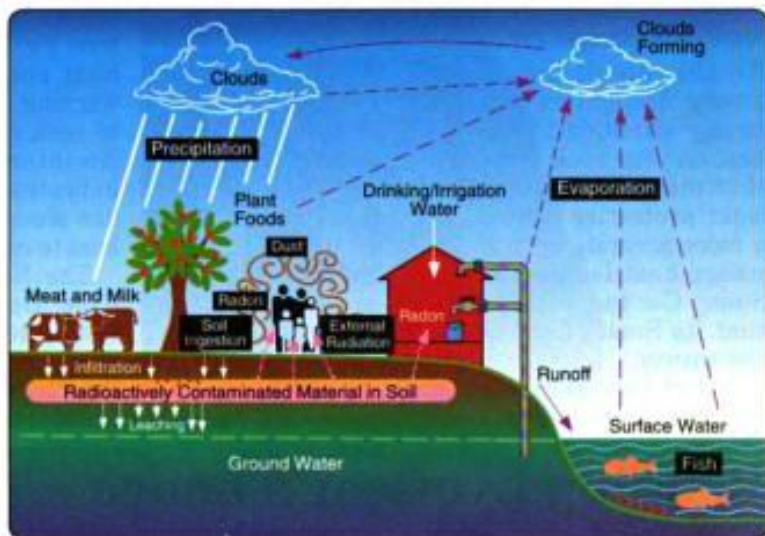
New Fusion Bottle

SAN DIEGO, CA—Magnetic bottles designed to ignite fusion—the nuclear reaction that powers the stars—can't be used to study the process in any detail. Within about a minute, the magnetic fields containing fusion's surface-of-the-Sun temperature plasmas break down.

About three years ago, researchers at UCLA discovered an unusual property of the metal beryllium that might make it the perfect material for fusion bottles. The researchers, who have since moved to the University of California at San Diego, are trying to determine whether the metal can be used to construct the type of continuously operating reactor that utilities will need if star power is to one day replace coal, oil and uranium.



Brilliant high-temperature plasma inside beryllium bottle.



Reusing Radioactive Scrap

ARGONNE, IL—It's a \$50 billion question: Are tools and building materials from nuclear plants waste or scrap?

If the government continues to consider it waste, owners of these facilities face a \$40 billion bill. As scrap, it could be sold for as much as \$10 billion.

The answer would be a no-brainer, except for this: Increasing the public's exposure to radiation—even slightly—also increases the risk of cancer and birth defects.

Pathways analysis allows researchers to assign risks to the various routes radioactive material may travel.

To help Congress more objectively compare the risks and benefits, Argonne National Laboratory created a computer model that traces the movements of radioactive materials through the environment.

Argonne concluded that recycling radioactive scrap would pose twice the health risk presented by the metals found in consumer products.

KILLER GARBAGE IN SPACE

Faster than speeding bullets, pieces of orbiting space junk could trash the space station.

BY JIM WILSON, Science/Technology Editor
PM Illustration by Paul DiMare

How much space junk orbits the Earth? A lot more than NASA expected when it began planning long-term manned missions. Three decades of sloppy spacekeeping have produced an estimated 35 million pieces of orbital debris, along with some nasty surprises. Astronauts fixing the Hubble Space Telescope spotted a $\frac{3}{4} \times \frac{3}{4}$ -in. gash in the nearsighted telescope's high-gain antenna. Space shuttle managers have been forced to spend more than \$5 million replacing debris-scarred cockpit windows. And, at least one satellite, the Russian Kosmos 1275, is believed to have been destroyed by high-flying junk.

No one knows precisely how much potentially mission-killing debris rings the planet or exactly where it is. "Although the mission of the Space Surveillance Network [SSN] is to track all man-made orbiting objects, technological and natural constraints serve to limit the effective tracking of objects smaller than 10cm [about 4 in.]," warns a White House Office of Science and Technology Policy (OSTP) internal planning document obtained by PM. The report also cautions that most of NASA's data on space junk—the

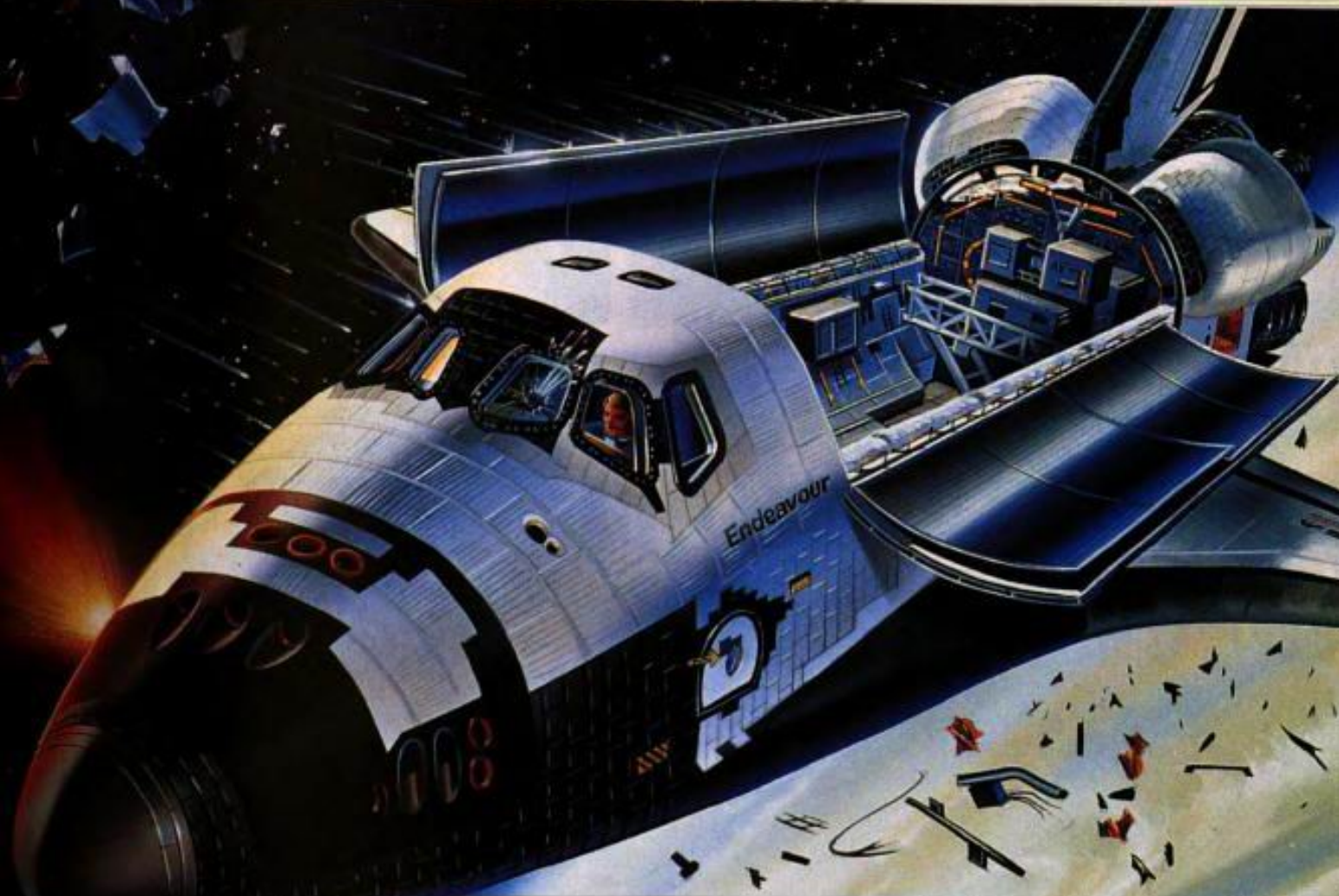


Most space trash, illustrated in this computer model, consists of debris less than the size of a grain of sand.

agency maintains that it isn't much of a problem—is derived from statistical studies. One of NASA's few pieces of hard evidence comes from counting the hits taken by its Long Duration Exposure Facility. During almost six years in space, the school-bus-size satellite received more than 32,000 dents and dings, about half of which came from man-made space trash, according to OSTP. The largest hit left a nearly $\frac{1}{4}$ -in.-dia. crater. While this sort of damage might seem trivial, OSTP has warned that debris of sizes 0.01 to 1cm (0.004 to 0.4 in.) produce impact damage that can be serious. For example, an aluminum sphere measuring only 0.05 in. in diameter and traveling through space at 22,000 mph delivers the same wallop as a .22-cal. long rifle bullet.

Of greatest concern to space experts are 110,000 so-called risk objects measuring between 0.4 and 4 in. "Objects larger than 1cm can produce catastrophic damage," says OSTP, which estimates that about 20,000 of the 110,000 risk objects are actually larger than 2 in. across. U.S. and former Soviet space programs are about equally responsible for creating most of the orbital debris, according to an inventory prepared by Teledyne Brown Engineering. This





Peppering from the smallest debris—believed to be paint flecks—routinely fractures protective covers on shuttle windows.



Shuttles flying long-duration microgravity missions will keep a bay door partially closed to protect the cooling system.

redesign of most sensors."

In 1992, NASA identified the parts of the shuttle most vulnerable to damage. Windows, it turns out, were not the prime trouble spots. The parts of the shuttle at highest risk are the freon-filled radiator loops. Located inside cargo-bay doors, they release into space the heat created by the shuttle's electrical systems and crew. A hit bad enough to disable one of the shuttle's two redundant cooling systems would require the shuttle to land within a day.

On longer missions, NASA pilots now partially close one of the shuttle's bay doors to act as a shield.

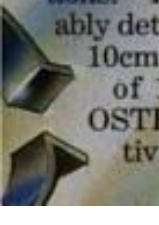
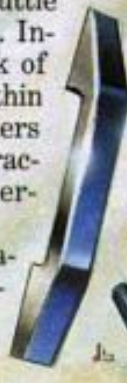
The time a spacecraft spends aloft also influences its risk of a damaging encounter with orbital debris. To protect the International Space Station, NASA has worked up a statistical analysis that shows its most vulnerable parts. They will be beefed up with shielding.

Despite its sophisticated warning system and improved shielding, NASA is also considering adding to the space station the same simple precaution motorists use to protect themselves against debris-strewn highways—packing a patch kit.

High-risk debris consists mostly of the remains of rockets and satellites that have broken up as the result of fuel or battery explosions.

OSTP says it is too expensive to equip the shuttle with an on-board garbage-spotting radar system. Instead, NASA relies on the SSN. If its network of space-watching sensors spot anything coming within about a mile and a half of the shuttle, NASA orders the pilot to make evasive maneuvers. Since this practice has been in effect, maneuvers have been performed on three occasions.

Space experts acknowledge that SSN has limitations. "The minimum-size object that can be reliably detected [by SSN] in low Earth orbit is about 10cm in diameter; yet avoidance of particles of 1cm dia. or larger is desirable," said OSTP. "This could require an increase in sensitivity of a factor of 100, requiring a major

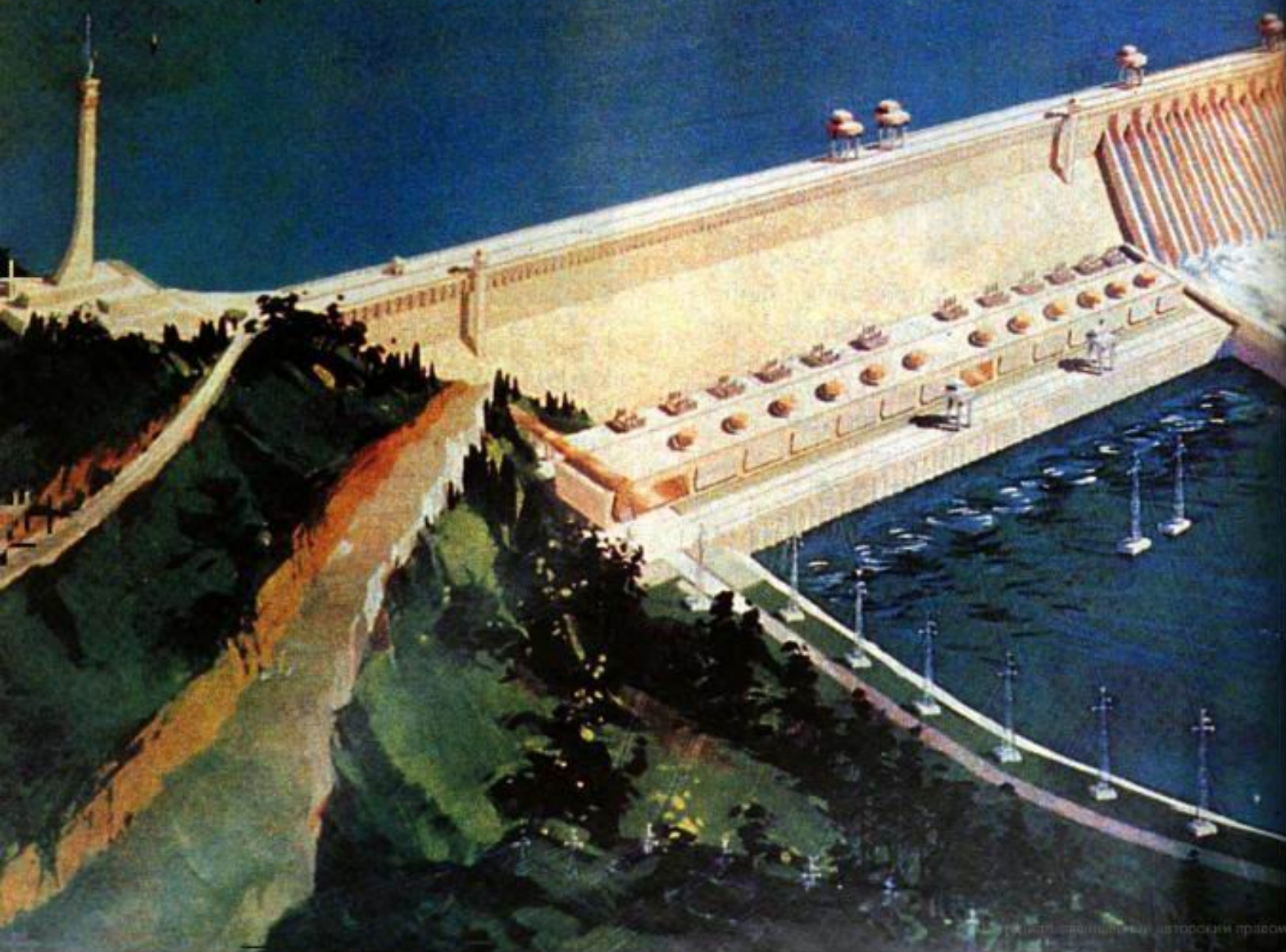


COVER STORY

TAMING THE YANGTZE

Lauded and lambasted, China's Three Gorges Dam may be the biggest civil-engineering project ever.

BY MIKE FILLON





● Every day, a gauzelike haze filters the sun over Sandouping, China. It comes from the now permanent dust cloud stirred by 40,000 workers as they dig and blast their way toward the bedrock that will anchor the Three Gorges Dam, the largest civil-engineering project undertaken in this century, and perhaps the largest of all time.

The superdam will stand near the midpoint of the 3716-mile Yangtze River, the world's fourth longest. Upstream, it collects sediment-rich water from the streams draining the Tibetan plateau. Downstream,

its yellow waters meander to the East China Sea. Here, just before Sandouping, the Qutang, Wu and Xiling gorges pinch the Yangtze with their sheer cliffs. For centuries, artists and poets have romanticized the breathtaking beauty. For just as long, shippers and upriver developers have cursed the furious rapids and whirlpools that impeded river travel.

All that is changing. One year into the dam's construction, the once picturesque valley of geometric rice patties below the Xiling has taken on the appearance of a quarry. When work finishes, the landscape's most striking feature will be a concrete cliff that soars 607 ft. into the sky and stretches 7054 ft., about six times the length of Hoover Dam. "Many of the things to be done at the Three Gorges Dam are unprecedented," says Dr. Eugene Chang, an engineer with Harza Engineering in Chicago, who has consulted on the project since 1978. "There will be things tried there that have never been done before, or will be done on a larger scale than before."

Scheduled to be completed in 2009, the superdam will cost \$12 billion, according to the project's sponsor, the People's Republic of China. Estimates by independent experts say it is more likely to be under construc-



Senior Engineer Yang Guowei (inset) explains the operation of the scale model used to study dam hydraulics.

tion until 2019, and cost \$70 billion or more. No one disagrees on the scale of the project. Building the dam will require excavating 104 million cu. yd. of soil and rock, moving in an additional 42 million cu. yd. and setting 34 million cu. yd. of concrete. The gross amount of material would duplicate the Great Pyramid 44 times over, making it only the second man-made object visible by telescope from the Moon. The other? China's original civil-engineering marvel, the Great Wall.

The size of the Three Gorges Dam is only part of the story. The structure will have 26 sets of 700-megawatt turbines and generators installed in its wings, churning out more than 18,000 megawatts of electricity. It outmuscles by 50% the current largest power-

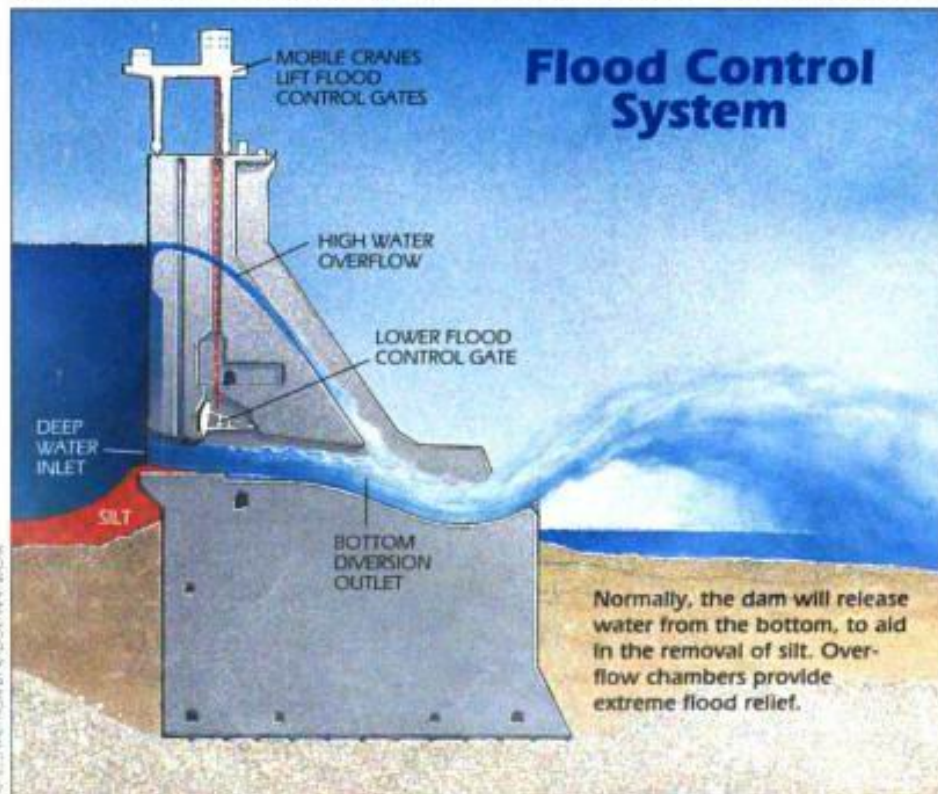
producing structure, the Itaipu Dam, which powers Brazil's megacities of São Paulo and Rio de Janeiro. In addition to making cheap electricity to encourage industrial development, the superdam will also make it more economical to move raw materials and finished goods into and out of the region. Once construction is complete, the dam will form a 418-sq.-mile reservoir. As the water rises—by as much as 295 ft. in some parts of the gorges—it will submerge more than 100 shoals. During dam construction, a 9843-ft.-long lock will allow ships weighing up to 6000 tons to pass through the worksite. Later, its main chamber will act as a sand sluicing gate, prolonging the useful life of the dam by removing the silt that settles

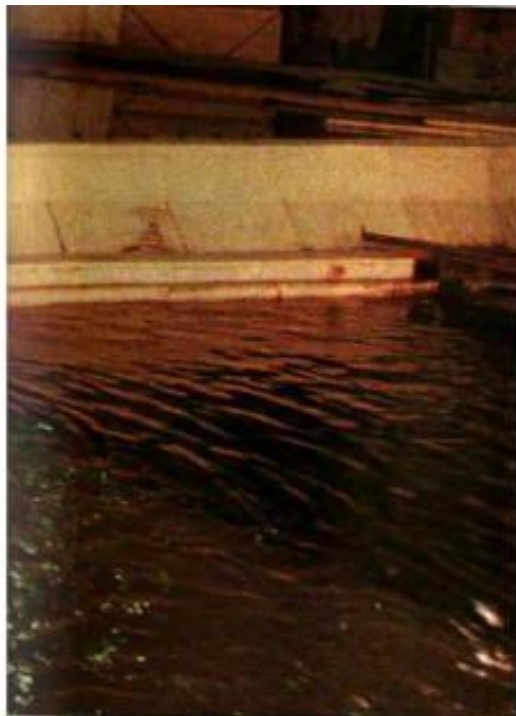
to the bottom when rapidly moving waters are slowed.

With double lanes and five steps, the permanent ship locks will dwarf the temporary channel. Building this structure requires excavating a 2395-ft.-long channel to a maximum depth of 579 ft. The locks will be the largest ever designed at $919 \times 112 \times 16$ ft. With the upstream river as much as 492 ft. higher than the downstream water, the water pressure requires that five different chambers be built at different elevations. The locks' huge gates will make it possible for 10,000-ton oceangoing ships to travel 1500 miles inland—as far as Chongqing—six months out of every year. The Chinese government believes the prospect of cheap electricity and inexpensive river transportation will transform the region surrounding Chongqing into a city of 15 million, making it an industrial powerhouse for the 21st century.

The superdam will also provide some flood relief in central and eastern China. Floods have inundated the Yangtze basin more than 200 times in the past 2000 years, including three times this century. In 1954, floodwaters covered nearly 8 million acres of land, causing 30,000 deaths and leaving some 19 million homeless. Flooding in 1931 and 1935 killed 200,000. The Chinese government estimates that major and minor flooding has cost more than 1 million lives this century.

The exact amount of flood protection the dam will actually provide for those living downriver is a subject of ongoing debate within the Chinese bureaucracy. Flood control managers say they want the dam filled to a level no more than 492 ft. above sea level. Then, before the start of the annual flood season, they want the level lowered to 459 ft. to accommodate surges



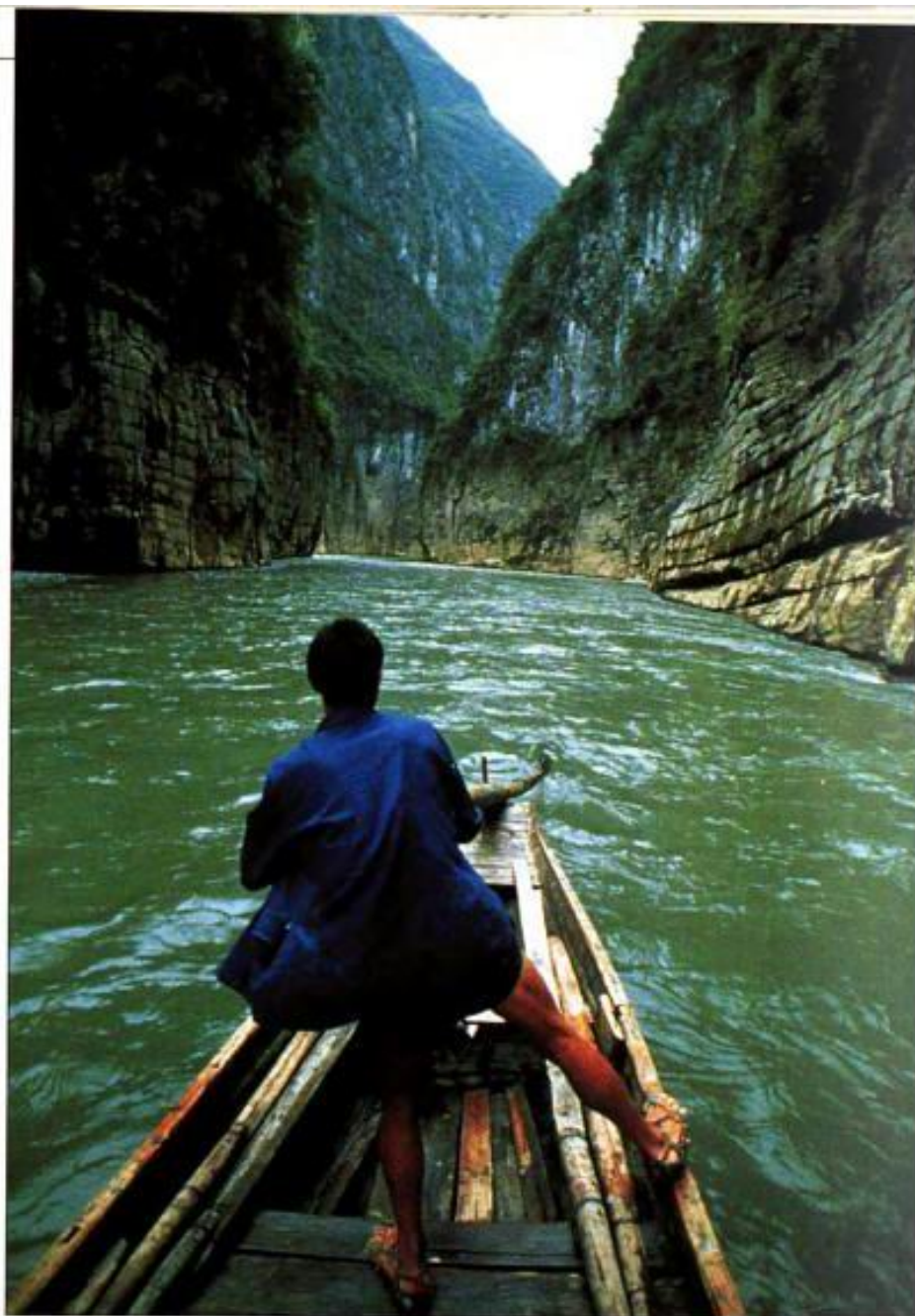


of upstream storm runoff. Electric-power management officials find this unacceptable. They say the levels that are ideal for flood control are insufficient to produce maximum power from the dam's generation stations. The government's most recent directive, a normal water level of 574 ft. above sea level, sides with the electrical production experts.

Maintaining a high "normal" water level will diminish the dam's promise of seasonal flood protection, but it is the permanent inundation of riverbanks that has raised the most complaints from critics of the project, which include the federally financed World Bank and the U.S. Army Corps of Engineers. While approvals from these organizations are not necessary for the Chinese to continue work on the project, they carry a good deal of weight in the international investment community. The Corps of Engineers has suggested that flood control could be better managed by building a series of smaller dams. These would not, however, be capable of generating the large amounts of cheap power China is hoping will attract industrial development.

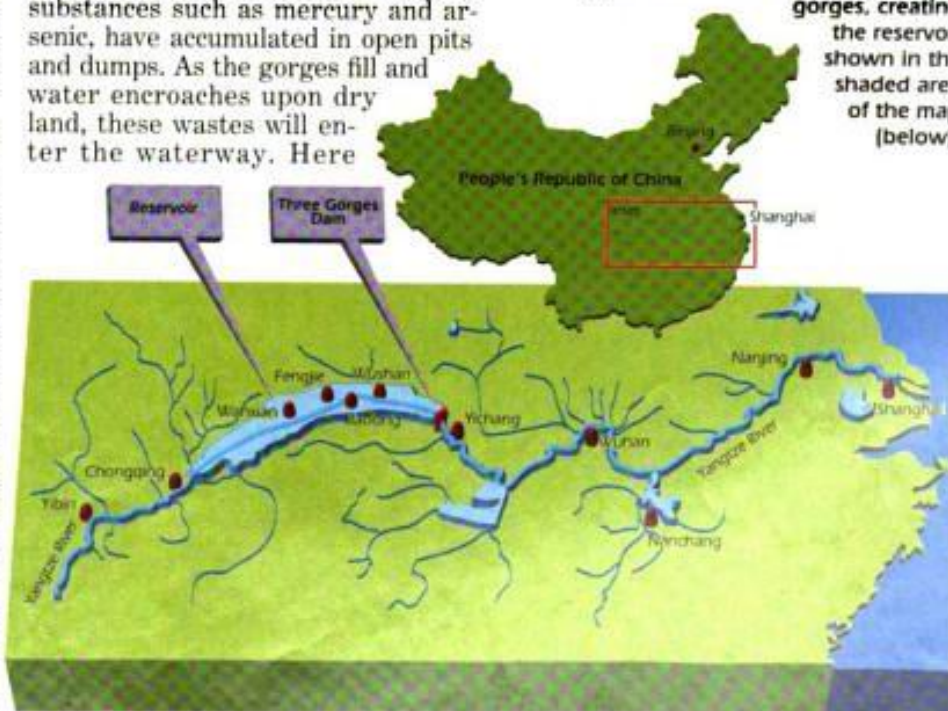
Another major objection is that the dam will submerge 104 towns and 100 significant archeological sites. The Yangtze River Water Resources Commission says that it will relocate 1.2 million people to make way for the project, and provide new land for 300,000 farmers. Soil experts for the Chinese Academy of Sciences have cautioned that a simple land trade wouldn't be equitable. They estimate it could take as much as 5 acres of mountain land to yield the harvest now taken from an acre of lowland soil.

Environmentalists worry about what inundation will do to the more densely developed urban and industrial areas. They point out that over

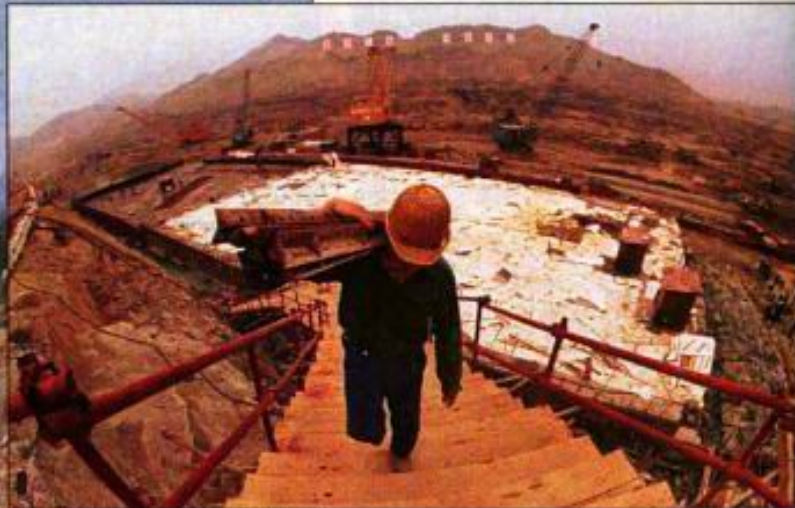


the past 1000 or so years, substantial amounts of toxic pollutants, including substances such as mercury and arsenic, have accumulated in open pits and dumps. As the gorges fill and water encroaches upon dry land, these wastes will enter the waterway. Here

Rapids and whirlpools (above) will disappear as the dam raises water in the gorges, creating the reservoir shown in the shaded area of the map (below)



TAMING THE YANGTZE



REUTERS/ROBERT NG-SCIENCE PHOTO



BRUCE CHAFF PHOTO

Three Gorges Dam has created jobs for 40,000 Chinese and multimillion-dollar export opportunities for American equipment makers (above). When complete, the dam will have a 2-lane lock system, shown to the right on the model (below left).

they will join with the discharges from an estimated 3000 mines and factories that, by U.S. standards, barely treat their wastewater.

Environmental scientists acknowledge that all waterways have some ability to naturally cleanse themselves of pollution. But many of them fear that the additional wastes entering the river as a result of filling the dam will outstrip this natural ability, causing massive long-term pollution problems. Pollution and the disruption of migratory patterns could endanger already rare species, including the white flag dolphin, cloud leopard, Siberian crane and 172 fish species.

The Chinese government acknowledges that the dam will pose environmental problems. But it also says that the project offers an environmental plus that outweighs all the minuses. If operated at the currently assigned high water levels, it could provide as much as one-ninth of China's total electrical production. To equal its energy production, Chinese industry would need to burn as much as 50 million tons of coal a year. Because hydropower production releases no atmospheric pollutants, the Chinese government says, Three Gorges will benefit everyone on the planet by reducing emissions of carbon dioxide, the "greenhouse" gas.

PM



BOETIC ILLUSTRATION

Popular Mechanics

JULY 1996

**OLYMPIC
SECRETS
THE
TECHNOLOGY
FACTOR**

COLOSSAL ENGINEERING

Three Gorges Dam Is The Most
Ambitious Project In The
History Of The World

**MEGAPOWER
FOR ANY PC**

How To Upgrade
For Lightning Speed

**HARLEY-DAVIDSON
vs. THE WANNABES**

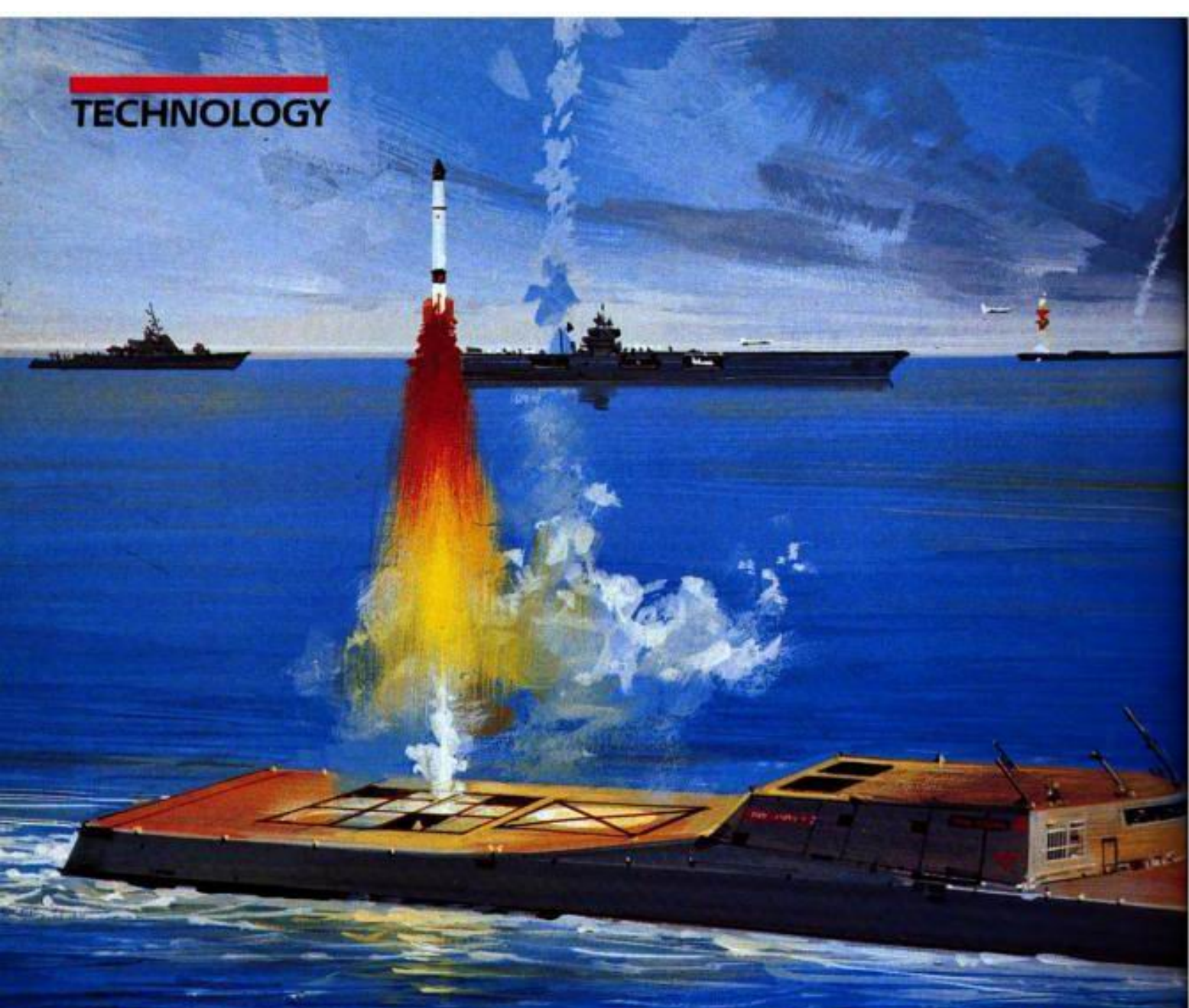
We Test The King Against
5 Copycat Cruisers



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ARSENAL SHIP

The Navy's planned class of stealthy attack ships delivers nothing but firepower.

BY SCOTT GOURLEY; PM Illustration by John Berkey

● It's the middle of the first decade of the 21st century, and a modernized Iraqi Army is conducting yet another round of maneuvers near the border of Kuwait. The U.S. responds to the hostile troop buildup cautiously, since elements of the Army's 82nd Airborne Division and the U.S. Marine Corps are already in Kuwait, participating in a multinational exercise. Suddenly, unlike past maneuvers that stopped short of the border, the Iraqi spearhead accelerates its advance, aiming to quickly seize significant oil assets in Kuwait.

Without warning, the spearhead enters the jaws of hell.

"He gets bloodied on day one," says Rear Adm. Alexander Krekich, director of surface warfare for the U.S. Navy. Krekich recently talked to *POPULAR MECHANICS* about the Navy's emerging concept for a

devastating new weapon it calls the Arsenal Ship. In Krekich's fictional scenario, the ship faced a hostile force that had attacked with little warning.

"With something like an Arsenal Ship on station—and for first-cut purposes, let's say [it's carrying] about 500 missiles—you could very easily do significant damage early on to stop a hostile force in its tracks. By doing that, you allow your forces to respond more effectively. You are able to counterattack earlier, which helps to reduce your casualties. The Arsenal Ship denies the enemy the advantage of surprise in the early stages of the conflict."

The Navy's Arsenal Ship concept has been under development for the past year and a half through a series of studies led by Adm. J.M. Boorda, chief of naval operations. The discussions focused on the Navy's emerging concept for a



Five hundred missiles, no waiting: The Arsenal Ship could support troops ashore with devastating firepower.

could deliver overwhelming firepower ashore during the early stages of a conflict.

Although the Navy has not released any drawings of the ship, descriptions paint a picture of a relatively low-cost vessel operated by a small crew. And while the Navy declines to cite specific cost projections, early estimates have reportedly ranged from \$500 to \$800 million for the ship itself. Crew size estimates run in the neighborhood of 20 to 100 personnel.

The vessel would carry as many as 500 missiles in a vertical launch configuration, and it would have a high degree of survivability, perhaps featuring a double hull or limited stealth characteristics. Its maintenance requirements would be low and it would be able to remain on station for extended periods, with crews rotating for 6-month tours of duty.

The Arsenal Ship is significantly different from the Metcalf Strike Cruiser concepts of the mid- to late 1980s. Referring to PM's July 1988 cover story, "America's New Fighting Ships," Krekich explains that the earlier concept showed a huge ship loaded with sensors and related combat systems. The design reflected the existence of both the Soviet Union and the Cold War. The new concept drops the sophisticated combat systems in favor of a simpler ship carrying a larger number of missiles.

The greater reliance on missiles reflects the maturation of missile technologies over the past 10 years. In addition, the Navy's Aegis Weapons System provides the Arsenal Ship with a complementary structure to perform the necessary combat-systems work. By linking through the sensors and combat systems of an

ARSENAL SHIP

accompanying Aegis cruiser, the Arsenal Ship could fire its sophisticated weapons at hostile forces with tremendous accuracy.

Arsenal Ship planners are currently addressing these linkage and accuracy challenges. "What we're looking for is a new way to do the links for the command and control architecture, the C4I [command, control, communications, computers and intelligence], if you will, and how all the data will come in," says Krekich. "The concept has gotten to this point: If you're going to support the forces ashore, the forces ashore will tell you where the missiles and gunfire should go. A latitude and longitude for each [target] is



The Vertical Launch System Mk 41 (above and below) can launch a wide variety of missiles. A Tomahawk is fired at right.

fine. We'll put a round there and put it there the first time. Hopefully, we can do that through a lot of links and not through a lot of manual input, as we did in Vietnam."

Boorda emphasizes that the Arsenal Ship is not designed for a specific weapon. The vessel will be able to fire any Defense Department weapon that



can be launched vertically. Candidates include the Standard missile, the Evolved Sea Sparrow missile (ESSM), varieties of the Tomahawk cruise missile, theater ballistic missile defense weapons, the Army Tactical Missile System (ATACMS) and even an advanced version of the Multiple Launch Rocket System (MLRS).

The Standard Missile-2 (SM-2), for example, is the Navy's primary surface-to-air fleet-defense weapon. Most recently, the Navy has been developing the SM-2 Block IV, which will operate in conjunction with the Aegis Weapons System and Vertical Launch System Mk 41 to provide improved all-weather fleet-area defense against both aircraft and cruise missiles. The ESSM reflects a kinematic upgrade to the AIM/RIM-7 Sea Sparrow air-to-air and surface-to-air missile. The upgrade also will provide increased lethality against high-speed antiship cruise missiles at greater intercept ranges.

The all-weather Tomahawk long-range subsonic cruise missile can be launched against targets on land or sea. The Tomahawk Land Attack Missile (TLAM/C) and the Tomahawk Antiship Missile (TASM) carry unitary conventional warheads, while the TLAM/D variant carries submunitions.

The existence of traditional Army systems such as ATACMS and MLRS in the Arsenal Ship's proposed weapons inventory reflects the Navy's intention of providing fire support to forces ashore. In the case of ATACMS, the Navy has already conducted at-sea firing tests (see *Tech Update*, page 32, Dec. '94). The Army used ATACMS Block I missiles in Operation Desert Storm and is likely to rely on the devastating missile in future conflicts.

According to Boorda, the mix of weapons on the Arsenal Ship would depend on the specific mission. For example, the vessel would carry plenty of ATACMS if the scenario called for significant artillery support. A rack of Tomahawks would be loaded if the vessel was to conduct first-day strikes in support of manned bombers. A situation with heavy anti-aircraft warfare operations or the threat of scud missiles would mandate a different missile mix.

"We've got to see what is reasonable and what we can accommodate," says Krekich. "But we are looking essentially to make a difference in the initial days of a conflict by providing heavy firepower. And, quite honestly, do significant damage to an enemy early on and not allow him to have any advantage whatsoever."

The first Arsenal Ship could enter the fleet by 2001 or 2002.

PM



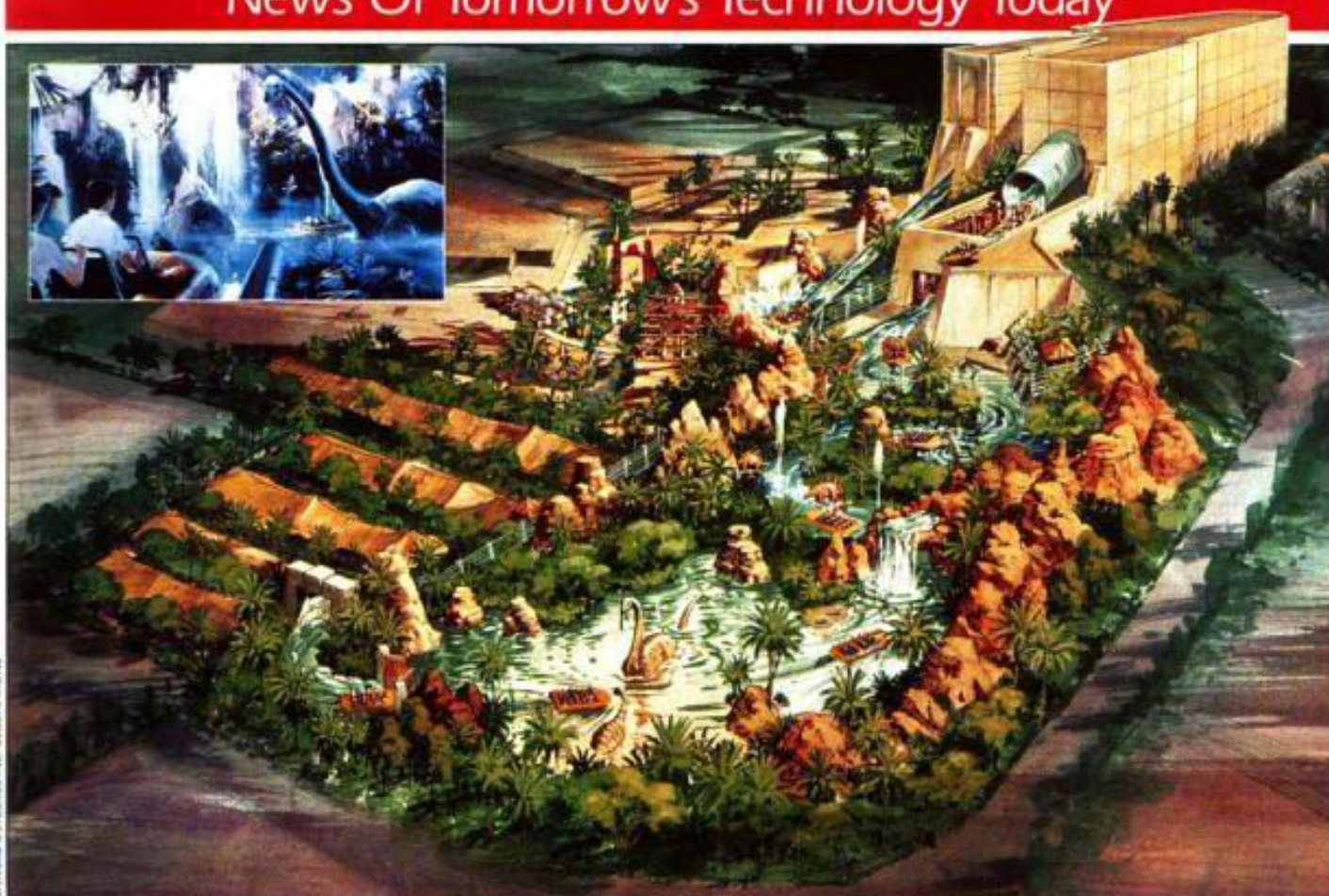
The Arsenal's Arsenal



Candidate missiles for the Arsenal Ship: THAAD knocks out tactical ballistic missiles. Tomahawk attacks targets on land or sea. ATACMS provides fire support to ground forces. Standard gives surface-to-air defense. ESSM targets antiship missiles.

TECH UPDATE

News Of Tomorrow's Technology Today



High-Pressure Hydraulics Power Life-Size Dinos

UNIVERSAL CITY, CA—Three years before the debut of the hit movie "Jurassic Park," Universal Studios Hollywood offered thrill-ride designer Neil Engel a \$100-million budget to create a rogue dinosaur adventure that could pump the adrenaline of even the most jaded of amusement park visitors.

"We broke all the rules and figured out new ones," says Engel, who previously designed the "Splash Mountain" attractions for Tokyo Disneyland and Walt Disney World.

By merging robotics with high-pressure-hydraulics technology—something new to the amusement industry, Engel says—Universal was able to build dinosaurs that are not only life-size but also can bend down to within feet of visitors' faces. To create more realistic eye contact between visitors and dinosaurs, Engel dressed up in a sensor-covered remote-control suit and played the part of, for exam-

ple, a raptor stalking dinner. A computer translated this motion into the monster's head and body movements.

Visitors to Universal Studios Hollywood will get to see Engel's work for themselves when "Jurassic Park—The Ride" opens this summer. What begins as a leisurely exploration of a dinosaur habitat—landscaped with more than 9000 trees, shrubs and plants—dissolves into chaos as a series of "accidents" unfolds. Guests who are one moment watching two extremely rambunctious *Psittacosauruses* splash water over the bow

Submerged motors propel the free-floating boats that visitors ride during their visit to the robotic "Jurassic Park."

of their 25-passenger free-floating boat suddenly find themselves threatened by escaped *Velociraptors* who strike with rattlesnake speed.

Before the 5½-minute adventure ends, guests plunge down an 84-ft. water drop that Universal describes as the fastest and steepest in amusement park history. "Even if you know the film, you still won't be ready for the terror that stalks you on the ride," Engel says.

Highlights This Month

- **Pocket Fax**—Road warriors read memos on the run.
- **Thirtysomething**—Pioneer 6 is still sending signals.
- **Laser Shootdown**—Illuminated rocket explodes.
- **Night Vision**—It's inexpensive and fits in your pocket.
- **Big Cats**—New ferries use twin-hull design.
- **Spreading Wings**—Plane changes shape in flight.
- **Back-Seat Driver**—Sensors spot road hazards.

Editor/Writer: Jim Wilson
Reporters: Mike Dillon, Kathleen Gleaves, Scott R. Gourley, David Hughes, Richard Schrader

TECH UPDATE

News Of Tomorrow's Technology Today



Rockets Could Ride The Maglev Express

WASHINGTON, DC—Think of it as the bullet train to space. The track: a 2½-mile magnetic-levitation (maglev) guideway that climbs through a tunnel carved up a mountainside. Suspended above this guideway, a flatbed sled carries a single-stage rocket spacecraft. Along the track, superconducting electromagnets fire in sequence, accelerating the sled to 600 mph. Then, at the mountain's peak, the spacecraft ignites its engines and leaps from the sled to continue its journey all the way into orbit.

That's the vision behind MagLifter, a future launch system being kicked around in Code XZ—NASA's advanced-concepts think tank. The technology could make the jump from blueprint to reality with a few billion dollars' investment. In return, say proponents, MagLifter could cut the high cost of space launch by serving as a reusable first stage.

Electromagnetic launchers have been proposed before (see Tech Update, page 16, April '88). But MagLifter has an edge. Unlike high-velocity coilguns, the system would subject payloads to no more than three times the pull of gravity. By limiting the stress of acceleration, MagLifter could accommodate such sensitive packages as commercial satellites.

Given a boost by the maglev accelerator track, the winged rocket could carry twice as much cargo as a ground-launched equivalent. Alternatively, it could haul the same payload

Electromagnetically accelerated rocket blasts off as it separates from carrier sled at mouth of MagLifter tunnel.

but be built far more robustly to enhance its reusability.

Right now, MagLifter advocates are looking at mountains in the Southwest as potential staging areas. Another option is to locate the system in Ecuador, where a 20,000-ft. peak would suit payloads destined for equatorial orbits. Meanwhile, designers hope to draw from the current X-33 and X-34 reusable-rocket programs to shape the rocket vehicle.

Highlights This Month

- **Construction Zone**—Latest on the space station.
- **Far Sighted**—Long-distance drone for spy missions.
- **Deep Heating**—Geothermal energy gets hot again.
- **Role Player**—F-22 fighter may serve double duty.
- **Net Profit**—Fish farming to ply deepest water yet.
- **Tire Walls**—Old rubber becomes new sound barrier.
- **Power Lines**—Railroads to carry solar electricity.

Writer/Editor: Gregory T. Pope
Reporters: John Boatman, Philip Chien,
Mike Fillon, Scott Gourley, Francis Hamit,
Rick Schrader

TECH UPDATE

News Of Tomorrow's Technology Today



Hybrid-Hulled Attack Frigate Levels The Waves

LAUREL, MD—Merge a hydrofoil with a small-waterplane-area twin hull (SWATH) and you get a HYSWAS, or hydrofoil small-waterplane-area ship. It's the Navy's latest experimental craft in the form of the just-launched 27-ft.-long *Quest*, built by Maritime Applied Physics Corp. The technology promises longer range, lower fuel consumption, higher speeds and better seakeeping ability than either the hydrofoil or the SWATH designs.

At rest or at low speeds, the HYSWAS vessel has a conventional profile. But once it picks up speed, an on-board computer angles the submerged foils to lift the craft out of the water into its flying position. Riding atop a single slender strut, the aluminum hull is relatively motionless as the waves ride up and down the strut. The single submerged hull, which contains fuel and machinery, provides 70% buoyant lift, while the submerged

hydrofoils give 30% dynamic lift.

Although HYSWAS technology has been on the drawing board for 20 years, *Quest* is the first floating prototype to be built in the United States. Initial test results are impressive: The vessel easily conquers 7-ft. waves while cruising at 33 knots. Maximum fuel efficiency is achieved at 20 knots, giving *Quest* a range in excess of 800 nautical miles. A single Cummins VTA-903 diesel engine drives a 3-blade 860mm propeller—the engine, turbocharged for its HYSWAS application, was originally designed to power the Army's Bradley tanks.

HYSWAS attack ship provides a stable gun and missile-launching platform while it slams through heavy seas at high speed.

At high speeds, the submerged bulbous hull produces more drag than a conventional hydrofoil, but the extra buoyancy more than compensates by helping to lift the upper hull out of the water. The extra lift allows the vessel to carry more fuel.

The Navy hopes to develop the HYSWAS design to produce high-speed manned and unmanned vessels capable of performing a variety of missions. Commercial applications include high-speed cargo ships and ferries.

Highlights This Month

- **From NASA, With Love**—Rendezvous with an asteroid.
- **Airliner-Style Chopper**—22 passengers to go.
- **Pint-Size 4x4**—Go-anywhere agility.
- **B-2 On Steroids**—1000-passenger flying wing.
- **In Your Ear**—Low-cost infrared thermometer.
- **Mini Atomic Clock**—Walnut-size timekeeper.
- **Old Reactor Gets New Life**—Tumor treatment, too.

Editor: Richard Stepler
Reporters: Philip Chien, Mike Dillon, Bill Garvey,
Kathleen Gleaves, Scott R. Gourley, Cliff Gromer,
David Hughes, Rick Schrader, Mark Wheeler

Popular Mechanics

FEBRUARY 1996

INSTALL A
BEAUTIFUL
HARDWOOD
FLOOR

CLASSIFIED

HOW WE SPY ON THE WORLD

For 35 Years, Our Super-Secret
Satellites Have Given Us The
Intelligence Edge

WILDEST VIDEO GAME YET

You Control The
Action With Your
Mind

**NOW!
PAGERS
THAT TALK**
Will They
Replace Your
Cell Phone?

**MOST FUN
YOU CAN
HAVE ON
WATER**

'96 Jet Boats
Pack Big Power,
Small Price

95



HIGH SPIES

For 35 years, top-secret reconnaissance satellites have provided America with a keyhole view of a troubled world.

BY PHILIP CHIEN

• In March 1994, a remarkable display went up inside the Central Intelligence Agency's headquarters, in Langley, Virginia, where only cleared personnel could view it. The exhibit: a still-classified Corona spacecraft, one of the original reconnaissance satellites of the 1960s. At the display's dedication ceremony, then-Director of Central Intelligence Richard Helms remarked that he hoped the satellite would one day

sit in the Smithsonian Institution, where Americans could recognize the role Corona played in shaping history.

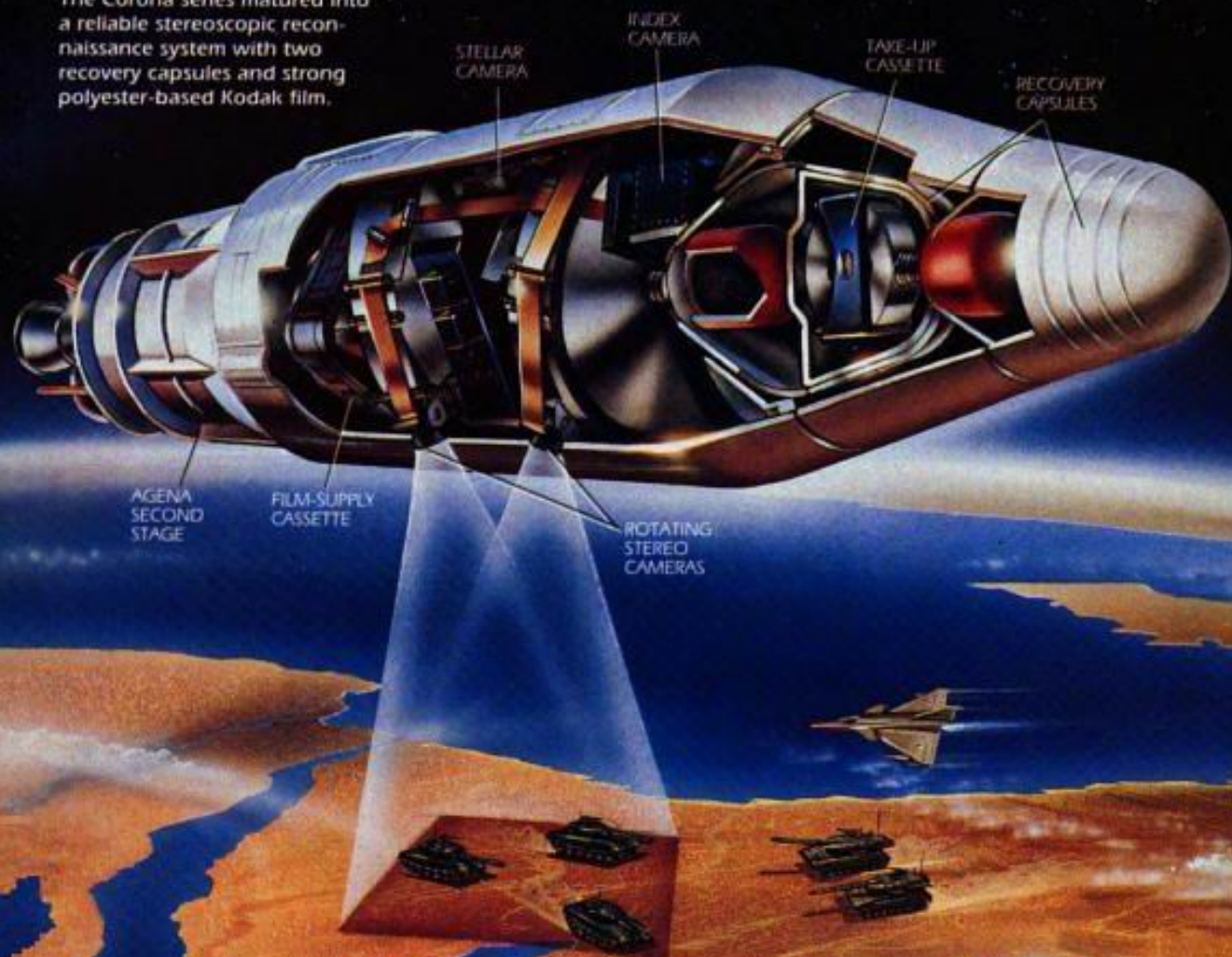
That day is coming—and probably much sooner than Helms thought. Today, the Air and Space Museum is preparing a permanent display of a KH-4B stereo camera and the re-entry capsule used on the very last Corona mission in 1972. On May 24, 1995, the intelligence community posthumously—and quite publicly—honored program manager Richard Bissell and Brig. Gen. Osmund Ritland, who died knowing they were pioneers and heroes but unable to tell their families just why.

All this was set into motion a year ago, when President Clinton issued Executive Order 12951, declassifying images from the Corona program and from two related subprograms. Now, just as Corona



KH-4B

The Corona series matured into a reliable stereoscopic reconnaissance system with two recovery capsules and strong polyester-based Kodak film.



once shed light on our Cold War foes, the declassification is illuminating the clandestine technology that gave us a leg up on those adversaries. Aerospace experts once strained to fathom the hidden workings of the program—just as they puzzle over today's reconnaissance satellites, which remain highly classified.

The Soviet Union's test firing of its first long-range ballistic missile in 1957 is what got Corona off the ground. Although the top-secret CIA/Lockheed U-2 enjoyed success, the spyplane was always one surface-to-air missile away from causing an international incident (which, of course, it did in 1960). So President Eisenhower authorized the CIA to develop photographic-reconnaissance satellites that could soar over "denied territory" with impunity. The Soviets could hardly complain. After all, they had already set a precedent of unrestricted satellite travel four

months earlier with Sputnik 1.

Built by Lockheed Missiles and Space, the Corona vehicles operated under the cover name Discoverer. Their purported objectives were scientific—lofting and recovering mice or other biological payloads to learn how spaceflight affected them. But the early Corona satellites turned out to be lessons in futility. The spacecraft, which were launched on Thor-Agena rockets, were supposed to orbit and then eject recoverable reentry capsules containing the exposed film. But Discoverer 1 never reached space—it crashed near the South Pole. Discoverer 2 flew a near-perfect mission, only to dump its reentry capsule in Norway near the Russian border. Discoverer 3 actually did carry mice, but they wound up in the Pacific Ocean.

Because there was no guarantee that Corona's recovery system would function, work took place simulta-



KH-11 FOLLOW-ON

Modern photoreconnaissance satellite features a high-resolution digital camera, on-board fuel supplies and a data-relay antenna to downlink imagery.

neously on another system, called Samos. With Samos, the film would be developed aboard the spacecraft, the photos scanned and the data radioed back to Earth. But Samos proved a bust and was dropped after only five test flights.

Early failures didn't faze the Corona team. "In those days we were pioneering everything," recalls Forrest McCartney, a flight controller in the program and now vice president for Atlas and Titan launch operations at Lockheed Martin. "When you couldn't recover the reentry vehicle it was a disappointment, and when you would get tumbling 'birds' it was a thrill a minute. It was pretty exciting—and a lot of fun." Ground controllers originally operated from an industrial park on Page Mill Road in Palo Alto, California. Later, they moved to the Air Force Station in Sunnyvale.

Number 13 turned out to be lucky for Corona. Launched August 10,

1960, its capsule carried not cameras but an American flag—the first man-made object to be recovered from orbit. The vehicle orbited 17 times. A communications foul-up prevented an Air Force C-119 aircraft from snaring the reentry capsule in midair. Instead, Navy divers had to fish it out of the ocean.

The next mission returned pictures—3000 ft. of film, covering 1.65 million square miles of the Soviet Union. The first useful image: a grainy shot of a Soviet bomber base just 400 miles west of Nome, Alaska. Resolution was crude: the camera could only discern objects 25 ft. across. Corona personnel destroyed the historic spacecraft, overreacting to secrecy instructions from President Eisenhower.

Cold War comfort

By the time the Discoverer series concluded in 1962, the Corona program

had evolved from a problem-plagued effort into a reliable intelligence asset. Corona continued as a classified project for another decade, however. In all, 145 satellites flew into space. Over the course of those 10 years, the resolution of Corona's camera sharpened to 6 ft., stereo cameras were introduced and a second "bucket," or reentry capsule, was added to permit longer missions with more film.

During its reign, Corona's achievements proved pivotal to American foreign policy. A steady return of overhead images kept the Pentagon on top of Soviet missile-site activity. Corona revealed the truth behind the "Missile Gap"—the headline issue in the 1960 presidential campaign. There was indeed a missile gap, but the United States had the upper hand. Furthermore, in 1964, a Corona photograph gave national-security officials a 2-month warning that China was about to join the nuclear club. In 1967, satel-

Countdown To Space-Station Age

HUNTSVILLE, AL—The recent space-shuttle visits to *Mir* set the clock ticking toward the launch of the International Space Station. NASA and its global partners are about 25 months from lofting the first components. But the world's biggest high-tech project is beginning to take shape.

Boeing welders and machinists have just finished their work on the first U.S.-built flight article—Node 1, which will connect the pressurized lab and habitation modules. The second node, linking the lab with European and Japanese facilities, is already complete and will soon begin pressure testing.

Meanwhile, in Russia, the Khrunichev enterprise has done the basic structural work on the Functional Energy Block—the first component slated for launch (in November 1997). Initialed the FGB from its Russian name, this space tug will provide propulsion during the station's early years. Node 1 will mate with this segment in December 1997.

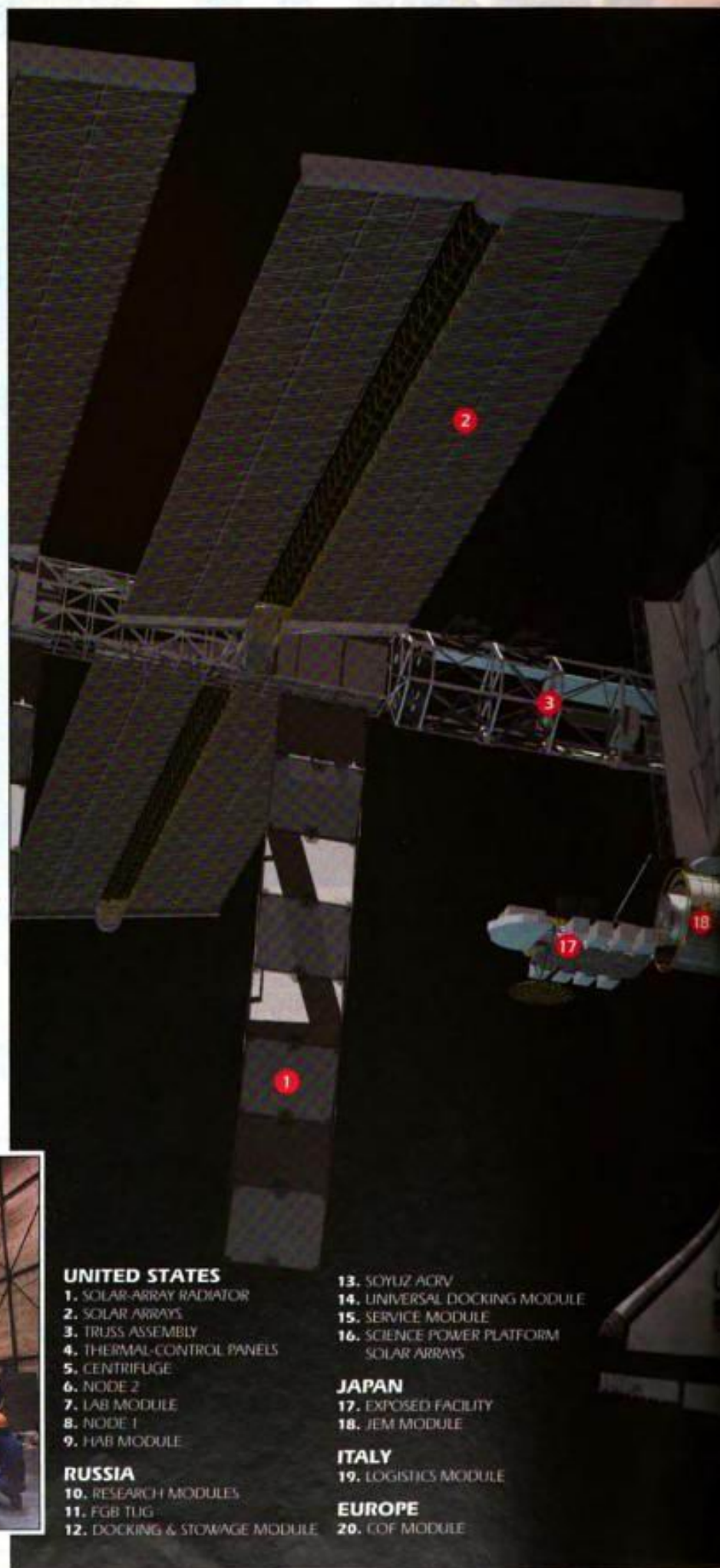
Other Russian components will go up later. One of the most important, the Service Module, will reboost the space station every day to counter atmospheric drag. The solar arrays on this module have been recently redesigned to augment the station's power supply during its construction period.

Japan is driving ahead aggressively with its contributions to the station. The free-flying prototype for the Japanese Exposed Facility is now in space, launched last March aboard an H-2 rocket.

But the outlook for the European elements remains murky. Member nations of the European Space Agency (ESA) are debating whether to continue funding the Columbus Orbiting Facility (COF), the lab originally planned for the canceled space station *Freedom*. Although Germany favors COF, France is now pushing to spend the money on a reusable space ferry. The other space-station partners have made it clear that if the ESA doesn't cough up the lab, it will be denied access to the station.



Node 1's aluminum exterior structure, weighing 5000 pounds, is now complete.



UNITED STATES

1. SOLAR-ARRAY RADIATOR
2. SOLAR ARRAYS
3. TRUSS ASSEMBLY
4. THERMAL-CONTROL PANELS
5. CENTRIFUGE
6. NODE 2
7. LAB MODULE
8. NODE 1
9. HAB MODULE

RUSSIA

10. RESEARCH MODULES
11. FGB TUG
12. DOCKING & STOWAGE MODULE

13. SOYUZ ACRV

14. UNIVERSAL DOCKING MODULE
15. SERVICE MODULE
16. SCIENCE POWER PLATFORM
SOLAR ARRAYS

JAPAN

17. EXPOSED FACILITY
18. JEM MODULE

ITALY

19. LOGISTICS MODULE

EUROPE

20. COF MODULE

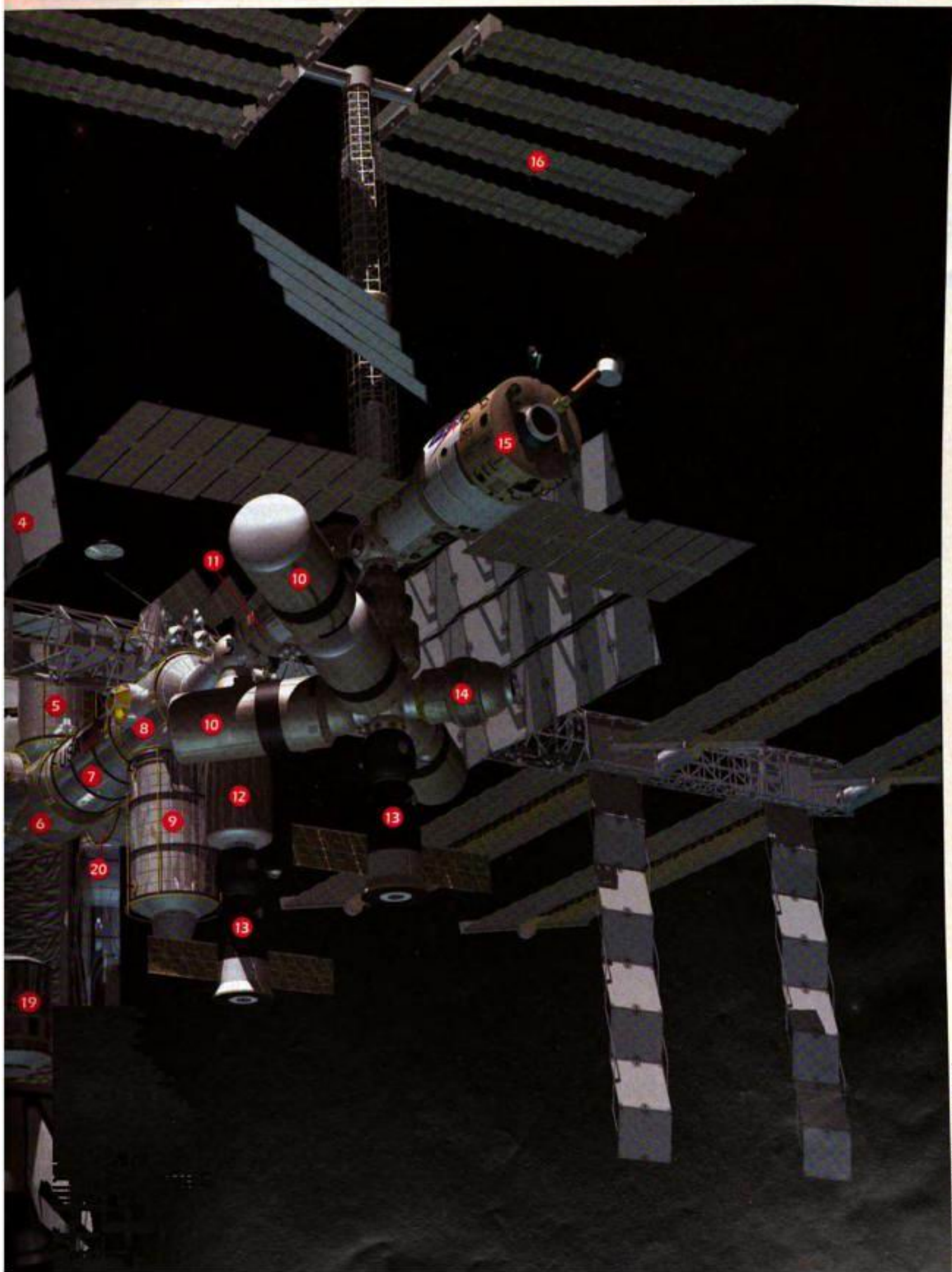


ILLUSTRATION BY JOHN FASANO AND ASSOCIATES



Inside front-line MEDFAST vehicle (right), teleoperated surgical instruments save soldier's life, while on-scene medic monitors his progress. At rear-echelon contingency hospital, surgeon (left) views 3D images and manipulates control devices. Signals are relayed through E-8C J-STARS surveillance aircraft. Stateside specialists (above left) offer real-time guidance via commercial satellite link.

LONG-DISTANCE OPERATORS

Robotics and telecommunications take the surgeon's skills anywhere in the world.

BY SCOTT GOURLEY; PM Illustration by Paul DiMare

● The year is 2005. A disintegrating political climate in Southwest Asia has once again put American soldiers in harm's way. Out ahead of an invasion force, Army Rangers are reconnoitering the desert landscape. But they've been spotted. And as a young sergeant lifts his scope to study the sands before him, an incoming rocket round showers his position with fragments of steel.

Twenty years ago, the attack would have left him miles from medical attention with life-threatening injuries. But today, medicine stretches out a long arm. From the moment the shards enter his chest cavity, the Ranger's personal status monitor—a wrist-worn

device that tracks his position and vital signs—begins transmitting information back to a battalion aid station. There, medics scan the data and opt to move directly to the wounded soldier.

Working quickly, they stabilize his most serious wounds and load him into a Life Support for Trauma And Transport (LSTAT) pod, a covered stretcher in which he is hooked up to a blood-infusion pump and a ventilator. During the short trip back to the aid station, the Northrop-built LSTAT hands off critical data. At the station, casualty-care workers transfer the soldier to a brand-new tracked vehicle. Called



TECH UPDATE

News Of Tomorrow's Technology Today



Robot Crabs Clear Surf Mines In A Pinch

ANAHEIM, CA—The surf zone. If you're riding a boogie board, you love it. If you're poised for an amphibious assault on a hostile shore, you hate it. The surf zone is a prime locale to stumble into a minefield. Not only is the water perilously shallow, but wave noise and turbidity hamper mine detection. And because a major mine-sweeping operation is sure to attract unwelcome attention, you can quickly lose the advantage of surprise.

The solution? A horde of mechanical crustaceans that can sneak in under the waves, detect mines and neutralize them en masse. Rockwell International and IS Robotics are developing these little suicide robots, or mites, called Autonomous Legged Underwater Vehicles (ALUVs). The Advanced Research Projects Agency and the Office of Naval Research are funding the effort.

The ALUV pays tribute to a crea-

ture that thrives beneath the breakers. A crab scuttles through the surf zone on legs that can dig in when the waves get rough. The Rockwell mite can also weather severe surf, burying itself in the sand by vibrating its legs.

What's more, legs are great structures to load with sensors, because they touch whatever they walk on. When the ALUV chances upon a mine, it clings to its quarry and then awaits a command from an operations center aboard a landing craft offshore. Once the signal is given, each

While an invasion force assembles offshore, autonomous legged robots walk through the surf zone hunting mines.

mite blows itself—and the mine—up.

Rockwell's prototype ALUV runs about 22 in. long and weighs 23 pounds, including 7 pounds of ballast. The mite has already proven itself capable of walking through the surf zone and finding targets. The next step, say engineers, is to build a second mite and have it communicate with the first, to make ALUV mine-sweeping more efficient.

Highlights This Month

- **Sneak Peek**—Stealth spy drone is unveiled.
- **Power Launches**—New rockets will double Delta's lift.
- **Out There**—The quest for extraterrestrial life resumes.
- **Sun Burners**—This year's solar-car showdown.
- **Air Cushion**—Next-generation hovercraft lose weight.
- **Genetic Ink**—Sign checks with your own DNA.
- **Fat Buster**—How the Russians clean out cholesterol.

Editor/Writer: Gregory T. Pope
Reporters: Philip Chien, Chris Chinnock, Mike Fillon,
William Garvey, Scott Gourley, Barry Rosenberg

Popular Mechanics

SEPTEMBER 1995

NEW APPLIANCES
THAT TAKE THE
WORK OUT OF
HOUSEWORK

BREAKING THE SOUND BARRIER —ON LAND!

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P81

MEGA-MODEMS FOR YOUR COMPUTER ARE HERE

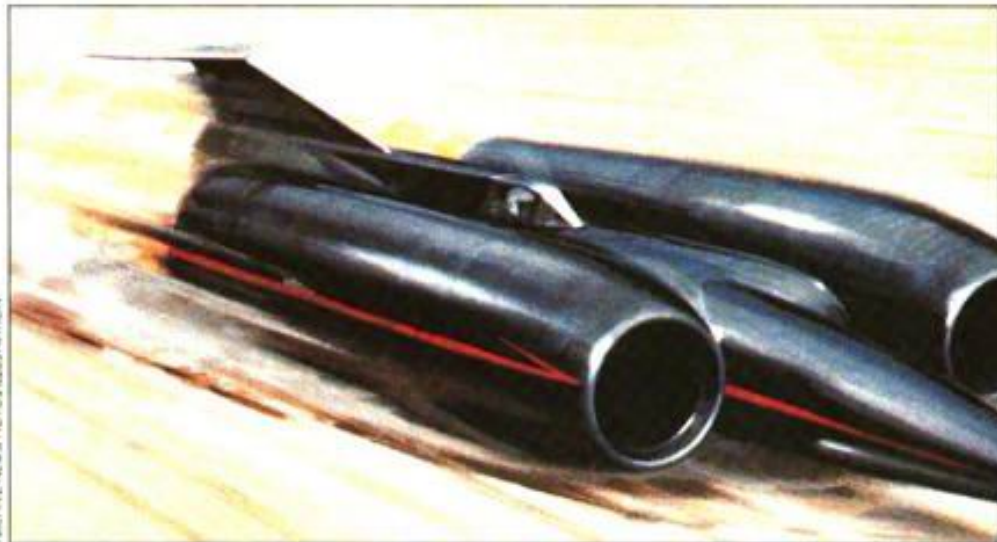


BREAKING THE —ON WHEELS!



These cars are designed to exceed Mach 1 and shatter existing land-speed records.

BY RICH TAYLOR, Contributing Editor



ARCHIVE NEWSPHOTOS ILLUSTRATION

● Englishman Richard Noble blasted to 633.468 miles per hour in his jet-powered Thrust II back in 1983 to claim the world land-speed record (LSR). He still is the proud owner of the top mark. And, while nobody has traveled faster on the ground since, technology has continued to accelerate over the past decade. In fact, today's racers plan to not merely break Noble's record, they intend to demolish it—and burst right through the sound barrier in the process.

As if land-borne jet travel isn't potentially dangerous enough, the contenders to the speed crown are facing a great unknown. Any object that reaches 1088 ft. per second—741.8 mph at sea level and 32° F—sets up a series of shock waves as it surpasses the speed of sound. What will happen when these intense waves of uneven pressure bounce back from the ground beneath a speeding vehicle as it breaks through the sound barrier?

Only one man claims to know, and he is Stan Bar-

rett. Barrett's Budweiser Rocket reportedly went transonic in 1979 at Edwards Air Force Base. The rear wheels were literally blown clear off the ground and Barrett pulled out of the throttle before completing his run.

The new generation of land-speed record vehicles looks like a squadron of weird fighter planes. The design intention is to let shock waves dissipate beneath the tubular fuselage while using wing-mounted ailerons to keep the vehicle on terra firma.

Here's a rundown of the current serious contenders that are out to set a new land-speed record.

Spirit Of America

Craig Breedlove was the first racer to break the barriers of 400, 500 and 600 mph. He held the LSR five separate times between 1963 and 1970, becoming a household name in the process. "Brave Speedlove" then retired to make his fortune in California real estate. Now 58, Breedlove is spending \$2.5 million to build a next-generation Spirit Of America vehicle.

Breedlove has eight employees working in a small shop in sleepy Rio Vista, California. The vehicle they're building is 47 ft. long, about 8½ ft. wide, and weighs 8500 pounds. It has a central fuselage with wings at the rear. The outboard wheels are covered by long aerodynamic fairings, and, of course, it's painted red, white and blue.

The vehicle's fuselage, wings and fairings use frames

SOUND BARRIER



welded from steel tubing, with special Alcoa aluminum alloy bulkheads and skin. There's a pointed nose in front of the cockpit, which in turn is sandwiched by the twin air intakes that are feeding a military surplus 48,000-hp jet engine originally used to power a Navy F-4 Phantom. About the only bits of truly unusual technology in evidence are 850-mph tires made with filament-wound Hercules-graphite.

Spirit Of America is close to completion. As we go to press, Breedlove expects to start testing at Black Rock Desert, Nevada.

If he succeeds, he will have set land-speed records some 32 years apart. That's got to be a record in itself.

Thrust SSC

Noble is building a new vehicle to defend his crown. Called Thrust Super-Sonic Car, it's powered by two Rolls-Royce Spey 205 jet engines, which produce a combined total of 100,000 hp. The driver sits between them behind a long pointed nose and ahead of an aircraft-style elevator/rudder tail section. Two forward wheels sit outboard of the side-mounted engines, and dual rear wheels—which are used for steering—are stagger-mounted inside the long-tailed Kevlar/carbon-fiber-bodied, monocoque-chassis vehicle.

Noble expects to make his first record attempt at Black Rock Desert right about now. Royal Air Force pilot Andrew Green will be at the controls. Noble, who retired from driving to become team coordinator, says the car is designed to go 800 mph.

Aussie Invader 2

Australian jet-car drag racer Rosco McGlashan hit 498.6 mph at Lake Gairdner, Australia, in March 1994.

Spirit Of America (above) and Thrust SSC (opposite page) are prime LSR contenders. Australian Challenge (below) is aiming for the wheel-driven record.



Theoretically, McGlashan's car has a potential top speed of 670 mph. That's enough to claim Noble's record, but nowhere near Mach 1.

Aussie Invader 2 was built in a small garage near Perth, Australia, by McGlashan and his friends. Invader 2 is designed around a single Atar 09C5 turbojet engine from a Mirage fighter plane built in the late 1950s. It produces about 15,000 pounds of thrust, roughly 30,000 hp. Invader 2 is just 27 ft. long, 4 ft. high and 7 ft. wide. The Atar engine is 22 ft. long and 3 ft. in diameter, so McGlashan's car is about as compact as it can be. The total weight of the craft is 11,000 pounds.

McGlashan's vehicle has a space frame of chromemoly tubing covered with a blunt fiberglass body. The driver sits in a cockpit set into the left side between the wheels.

The most high-tech components on Invader 2 are its four forged-aluminum wheels. These have ribbed rims and are designed to run without tires. Racing-style carbon-fiber disc brakes and two parachutes are used to stop the vehicle. McGlashan is sponsored by an Australian television network, so whatever happens to Invader 2 will be broadcast live for all the world to see.

Green Monster No. 27

Pioneer hot-rod Art Arfons, of Akron, Ohio, became famous with a series of aeroengined dragsters, all painted John Deere Green and called Green Monster. In 1965, he briefly held the land-speed record at 576.553 mph with a homebuilt car powered by a



For The Record

● There is an excellent chance that Craig Breedlove will make history, and his Spirit Of America could conceivably be enshrined at the Smithsonian Institution in Washington, D.C. The car will be a billboard for the names of a host of corporate sponsors. But there will be a place on the car where individuals who are sponsoring members of the team will have their names inscribed. Anyone can become a sponsor. For more information, write SOA/WSRT, 200 N. Front St., Rio Vista, CA 94571, or call (510) 855-9902. The America Online e-mail address is SOAWSRT@AOL.COM.

GE J79 turbojet. In November 1966, Arfons survived the world's fastest accident—at 610 mph.

Two years ago, Arfons completed another LSR car, which, though still called Green Monster, is painted red, white and blue. It's a tiny missile just under 25 ft. long, 2 ft. wide and 3 ft. high (5 ft. to the top of the tail fin). It's built around a small biz-jet engine rated at only 9000 hp—but then, Arfons claims this Green Monster weighs an ultralight 1800 pounds.

The frame is 4130 chromemoly tubing, covered by a Kevlar-reinforced

fiberglass body. There are two front wheels set in tandem, each 26 in. in diameter and 3 in. wide. Forged by Alcoa, these aluminum wheels, like McGlashan's, carry no tires. Each rear wheel is carried on a rigid strut projecting from the side of the car and is only 16 in. in diameter and 2 in. wide.

Maverick

Much more costly than any of these other LSR programs, McLaren Advanced Vehicle's (MAV's) contender is still in the planning stages. To be called Maverick, it measures 42 ft.



long, 17 ft. wide and 11 ft. high. There's a wheel at the end of each wing, plus two wheels set side by side under the nose. A third of its 6600-pound weight is a Rolls-Royce RB199 Mk104 gas-turbine engine rated at 38,000 hp, which should push the Maverick from 0 to 850 mph in less than 40 seconds if a course that's long enough can be found.

The vehicle is made of Kevlar/carbon fiber. Like a fighter pilot, the driver will be strapped into an ejector seat programmed to blast him free if, as McLaren's Ron Dennis delicately puts it, "the angles experienced by the computer are inconsistent with the wheels being on the ground."

Unlike most other LSR machines, which use a fixed suspension, the Maverick has a computerized active suspension that's derived from McLaren's Formula One racers. The engineers hope this will allow the Maverick to smoothly traverse the Mach 1 "speed bump."

The team plans to make its LSR attempt by the summer of 1998.



BRITISH THRUST

Englishman Richard Noble and his Thrust II jet-powered car currently own the land-speed record at a shade over 633 mph. Noble intends to head a team to break his own record and Mach 1 with a twin-jet vehicle piloted by Andrew Green. The Thrust SSC has two Rolls-Royce jets for 100,000 hp, four wheels, a monocoque chassis and Kevlar/carbon-fiber body. SSC is designed for 800 mph.



While all of these jet-powered vehicles are chasing the speed of sound and the ultimate land-speed record, there's a whole 'nother show going on. That's the quest for the wheel-driven speed record. On November 13, 1965, California hot-rodder Bob Summers set that record at 409.277 mph in the Summers Brothers' homebuilt Goldenrod. Then, in August 1991, Al Teague posted a supercharged-single engine record for wheel-driven vehicles at 409.986. There are still

FUEL TANK
HOLDS 95 GALLONS
OF UNLEADED GAS

STEERING FIN
PIVOTS 2"

SPIRIT OF AMERICA

True American hero Craig Breedlove holds a model of the real thing, Spirit Of America. Former LSR record holder Breedlove intends to ride nearly 50,000 hp worth of an F-4 fighter jet engine across Black Rock Desert. The details of Spirit Of America show that it may not be unusual in design, but it is very purposeful.

SIDE-MOUNTED JET AIR INTAKES

CARVED-BILLET BULKHEAD

COCKPIT

STEERING-FIN
CONTROL
WHEEL

THREE FRONT
WHEELS MOUNTED
ON SINGLE AXLE

BRAKE SHOE

THROTTLE
CONTROL ROD

GAS PEDAL

folks who intend to better that feat, and they are as follows:

Australian Challenge

Australian hot-rodder Glen Davis hopes to break the Summers Brothers' and Teague's records by hitting 500 mph. His Challenge looks like a 41-ft. pencil, with small bulges around the tires. Davis will recline in a cockpit enclosed in the pointed nose ahead of the front wheels. Small tail fins flank the chisel-point tail. The chassis is a simple monocoque of sheet steel. The body is a Kevlar/carbon-fiber sandwich with balsa cores. Davis has designed an all-independent suspension with hydropneumatic load-leveling. He's also chosen two surplus Rolls-Royce Meteor Mk4B twin-turbocharged V12 tank engines for power, placed front to front in the center of the

chassis. Running on methanol, each 27-liter engine produces only 2500 hp at 3800 rpm—a very mild state of tune for a racing powerplant.

Team Natural Gas Streamliner

Indy driver Lyn St. James is putting together an attempt on the wheel-driven record. Built by Indianapolis-based chassis constructor Bob Riley, St. James's car is very conventional. Imagine a typical midengine Top Fuel dragster. Add awd for traction and a track less than 3 ft. for smaller frontal area. Cover its tubular space frame with a streamlined aluminum/composite body less than 3 ft. high, 3 ft.

wide and 28 ft. long. Even with the driver, the car should weigh only 2800 pounds ready to run.

Running on methane, St. James's car will produce only 2200 hp from a supercharged 570-cu.-in. V8. It should be more than enough to push her to 450 mph. If Davis has his way, that may not be fast enough.

At the very least, St. James should be able to grab the women's LSR, held since 1965 by Lee Breedlove, Craig's former wife, at 308.560 mph. **FM**



PHOTO BY BILL NATION



AUSTRALIAN CHALLENGE

The biggest threat to the Summers Brothers' and Al Teague's wheel-driven speed records is from the twin-V12-powered Australian Challenge. Built and driven by Aussie hot-rodder Glen Davis, the Australian Challenge is a 41-ft.-long all-wheel-drive pencil capable of going 500 mph. The methanol-powered turbocharged V12s each drive a set of wheels.



AUSTRALIAN CHALLENGE PHOTO AND ILLUSTRATION

Tomorrow's trucks

streamlined COE (cab-over-engine) tractors. Ryder's idea was to test truck aerodynamics—to try to see in actual on-the-road practice how streamlining affects long-haul fuel economy.

Nine of Ryder's slope-nosed prototypes were put into service—three by Ryder and six in other companies. The tractors themselves were totally new, not just re-bodied versions of production tractors. They used stock Cummins diesel engines so fuel economy could be checked against conventional rigs with identical powerplants.

Oregon trucker Dean Hobbensiefen, working with one-eighth scale models, evolved the shape of these Ryder COEs. Ryder engineer Harleigh Holmes and University of Maryland researchers refined the original shape by placing scale-model trucks into the university's wind tunnel. In arriving at the final shape, they tried various fairings, spoilers, skirts, V'd trailer noses, seals between tractor and trailer and so forth.

In recent 290-mile-loop test runs in Indiana (240 miles on interstates and 50 miles on city streets), the Ryder protos posted 33.5 percent better gas mileage than equivalent "normal" trucks. The conventional trucks averaged 5.0 mpg; the streamlined Ryder rigs got 6.7 mpg. In terms of money, that's a saving of \$4100 a year based on 100,000 miles of driving and 50 cents a gallon for diesel fuel.

Nose-cone tractor

Another very interesting concept has been developed by Strick, Inc., the trailer manufacturer in Fort Washington, Pa. Strick engineers have

attempted to maximize the carrying capacity of the largest legal tractor/trailer combinations by reducing the size of the tractor and thus upping the volume of the trailer.

They've tucked a small, streamlined, one-man tractor under the leading edge of a lengthened and lowered trailer. The driver, surrounded by glass in this small "nose cone," sits at about the same height as he would in a conventional car.

The Strick design puts the trailer pivot atop the cab roof, and the concept was originally proposed with four-wheel steering, high-flotation single tires and up to 80,000-pound GVW. The Strick truck puts primary emphasis on cargo capacity and only secondary stress on streamlining. Spokesman Ron Zubko says that Strick is now going into its second generation of the same basic idea.

What does all this activity mean? When and how will the truck revolution come?

Economic incentive

It's hard to give an exact timetable, but during the Ford administration, there was talk suggesting that truckers "voluntarily" boost fuel economy by 18 to 25 percent. There's nothing the industry would rather do. Whether President Carter's energy policy will speed up fuel-economy measures remains to be seen.

You can bet, though, that either way whether brought about by government recommendations or not—the trucks that you see coming down the road in the future will be more streamlined. It's inevitable. ★ ★ ★

SOME IDEAS YOU'LL SEE ON TRUCKS OF THE FUTURE

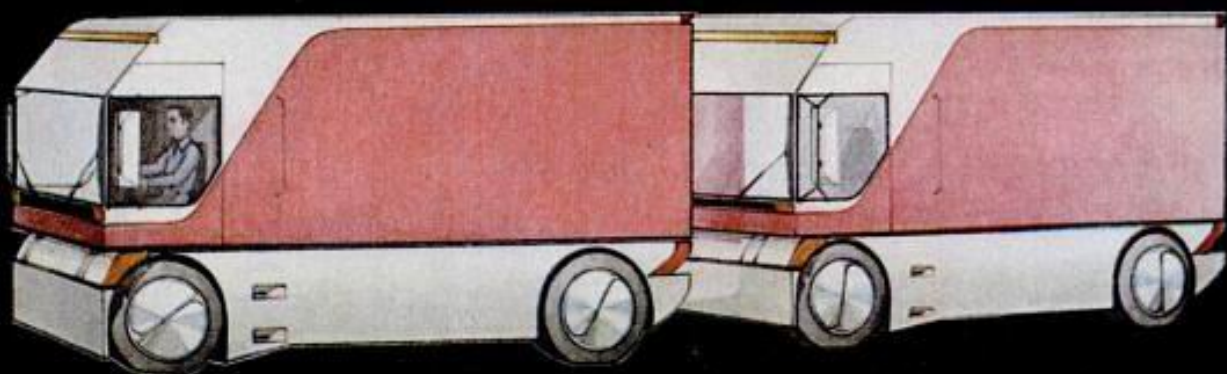
LONG, SLOPING WINDSHIELD OF ULTRATHIN TEMPERED GLASS GIVES GOOD VISIBILITY AND RACE-CAR AERODYNAMICS.



CAB TAPERS OR NARROWS TOWARD FRONT TO CUT THROUGH THE AIR MORE EFFICIENTLY. THIS REQUIRES THE FRONT AXLE TO BE MOVED AFT.

SEPARATE, SELF-POWERED TRUCKS ARE COUPLED TOGETHER WITH ONE DRIVER IN THE FRONT UNIT.

INDIVIDUAL UNITS ARE USED DURING THE DAY FOR CITY PICKUP AND DELIVERY. AT NIGHT, TWO OR MORE UNITS ARE DISPATCHED OVER THE ROAD WITH ONE DRIVER.



FLEXIBLE, LIGHTWEIGHT POLYPROPYLENE
ACCORDION ELEMENT BETWEEN
ALL UNITS CAN IMPROVE
AERODYNAMICS 25 PERCENT.

FULL-LENGTH LOWER
BODY SKIRTS ELIMINATE
TURBULENCE UNDER
TRAILER. EACH SKIRT CAN
BE QUICKLY REMOVED FOR
WHEEL, TIRE AND BRAKE
SERVICE.

CONVENTIONAL CAB:

ENGINE-CAB POSITION IS
REVERSED FOR IMPROVED
VISIBILITY BY ELIMINATING
LONG HOOD. GOOD FOR WESTERN
STATES WHERE BRIDGE LAWS
REQUIRE A LONG WHEELBASE.



CAB HAS ONLY TWO AXLES, BOTH
DRIVEN. ELIMINATION OF
SEPARATE STEERING AXLE REDUCES
WEIGHT, TIRE FRICTION ON ROAD.
TANDEM STEERING SYSTEM HAS BEEN
USED IN EUROPE FOR MANY YEARS.

LCF (LOW-CAB-FORWARD):

GOOD FOR CHASSIS-
CAB CITY TRUCKS
AND MULTISTOP TRUCKS.



BACK-OF-CAB AREA HAS
CLEAN SURFACES FOR IMPROVED
AERODYNAMICS. TRAILER
FITS SNUGLY AGAINST THESE
SURFACES BY MEANS OF
ACCORDION-PLEATED DIAPHRAGM.

COE (CAB-OVER-ENGINE):

GOOD FOR EASTERN
STATES AND CITIES
WHERE A SHORT
WHEELBASE IS REQUIRED.

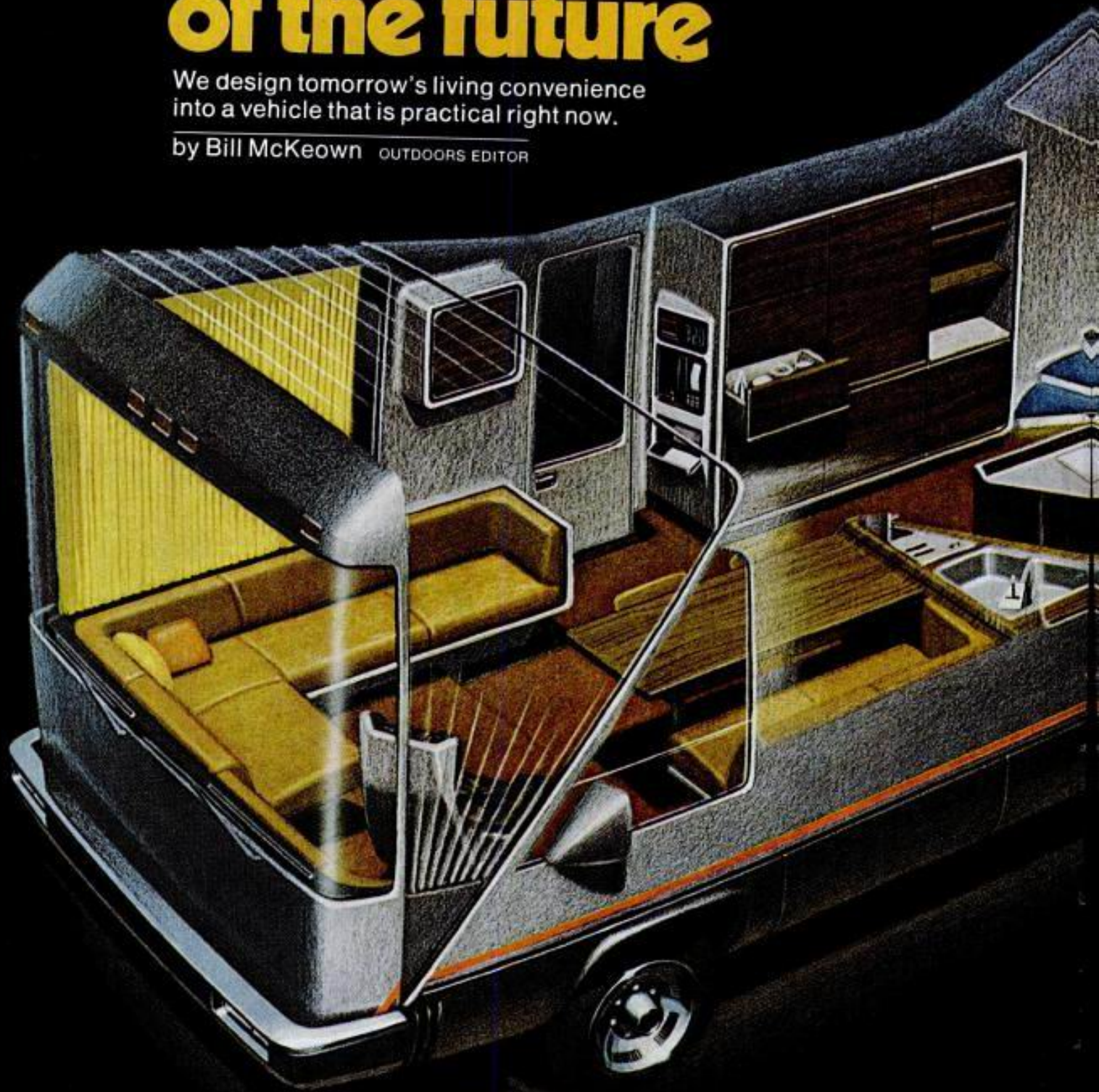


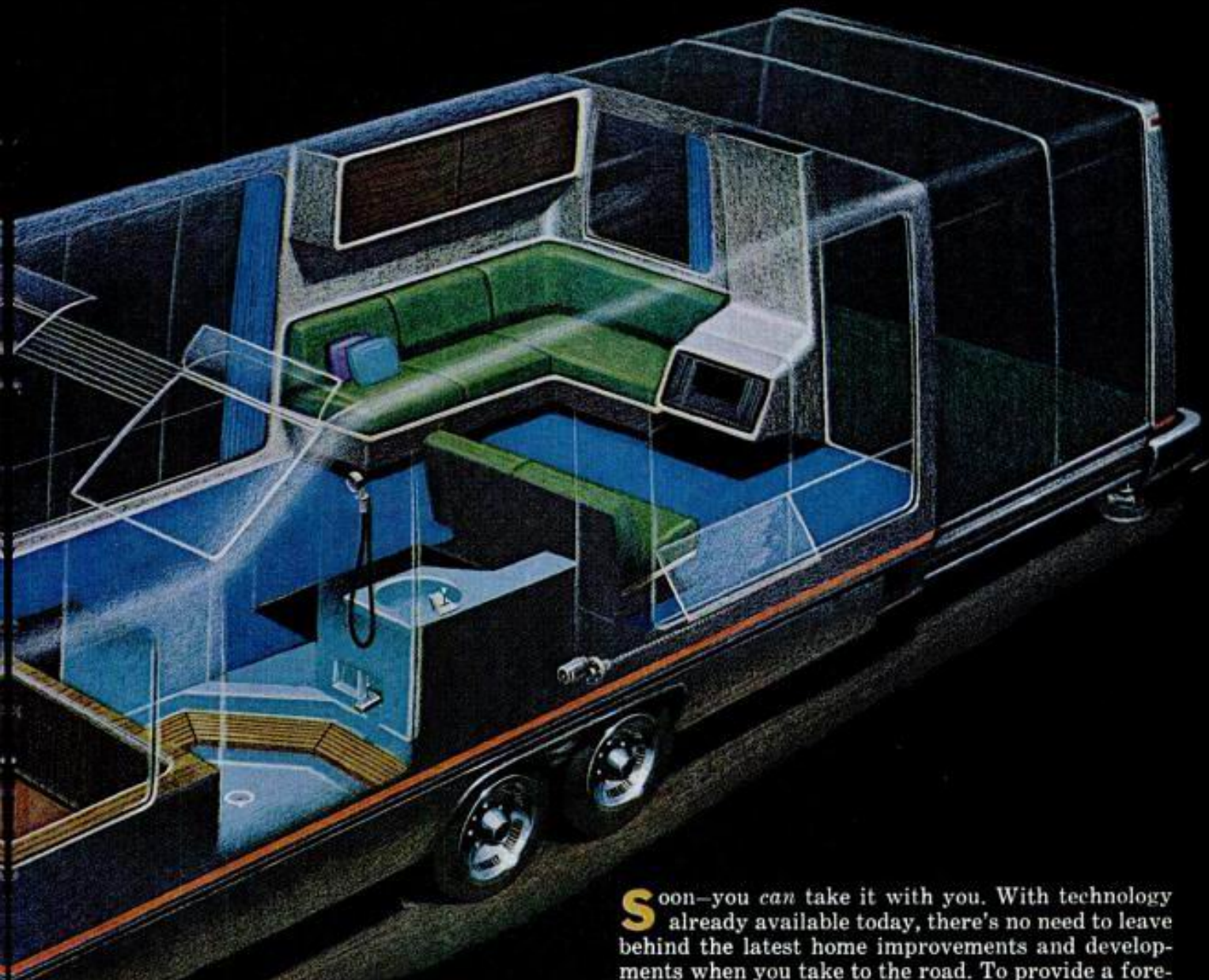
WHEN WHEELS ARE
EXPOSED, DEEPLY
RECESSED CENTERS
ARE COVERED WITH
FLUSH DISCS TO REDUCE
TURBULENCE.

PM's motor home of the future

We design tomorrow's living convenience into a vehicle that is practical right now.

by Bill McKeown OUTDOORS EDITOR





Soon—you can take it with you. With technology already available today, there's no need to leave behind the latest home improvements and developments when you take to the road. To provide a forecast of things to come, *Popular Mechanics* worked with some of the top transportation designers to fit these predictions into a practical package on wheels.

More than the comforts of many a home are presented here in PM's prototype vehicle. It incorporates ideas by industrial designer Ed Westcott and Richard Lee Kessler of Westcott Associates, Westport, Conn., and illustrator Dale Gustafson. Westcott was formerly a designer for Ford and Chrysler, and helped create the Metroliner and airport people-movers. Gustafson spent years in Detroit working on automotive designs for General Motors. The clean aerodynamic lines and light strong materials of aircraft construction used here won't cut the cost of our RV, but will add to safety, durability and fuel economy. Complementing the sleek exterior, and equally important, is the roomy interior arrangement with maximum use of all available space, plus creation of some to spare.

Pull into a campsite of the future and you first expand the front lounge by pivoting forward the streamlined nose. This provides full headroom and, with the front in vertical position, the driving con-



Gone with the wind-resisting frontal area is the shoebox look. Clean aerodynamic lines and strong, light construction aid appearance and fuel economy when front pivots back for driving.

trols and instrument panel can be swung down out of sight, driver's seat reversed and slid forward, and the padded dash hinged down to form a couch that can later become a bed. Instead of individual dials on the dash, digital readouts can give information selected by pushbuttons. A few years from now, speed signs along the road may emit rays that activate a vehicle sensor to display speed limits ahead on a dash panel.

Though PM's travel home is planned for continuous touring and does not have the tilt-out room extenders that are already available in some large park-model travel trailers which stay at one campground for months at a time, it can stretch out quickly in back as well as forward. The split-level layout with raised lounge and bedroom aft makes possible the storage of a patio floor underneath. Actuate the screw-drive mechanism shown and the back of the RV extends to accordion-out a 6-foot back porch. Lower the supporting legs, set up deck chairs, open the back of the lounge fireplace, and get ready for a barbecue as the sun goes down.

Because a traveler often follows the sun to regions of balmy weather, the travel home's roof has a number of flush-mounted solar energy panels to generate power for charging batteries, running communications equipment and heating water as an occasional option in place of generated or plug-in power. Sunlight also floods in through skylights over the sauna and the steps to the upper level, as well as in the large picture windows on both sides of the vehicle. The raised rear section allows storage of airconditioners and the heating unit, a clean roof line results and, without top-mounted conditioners, clearance height is less than that of many motor homes today.

While water and fuel tanks under the raised flooring allow an increased range of action and camping away from hookups, minimum space is required for gray water and sewage holding tanks since the incinerator systems now being introduced are fully utilized.

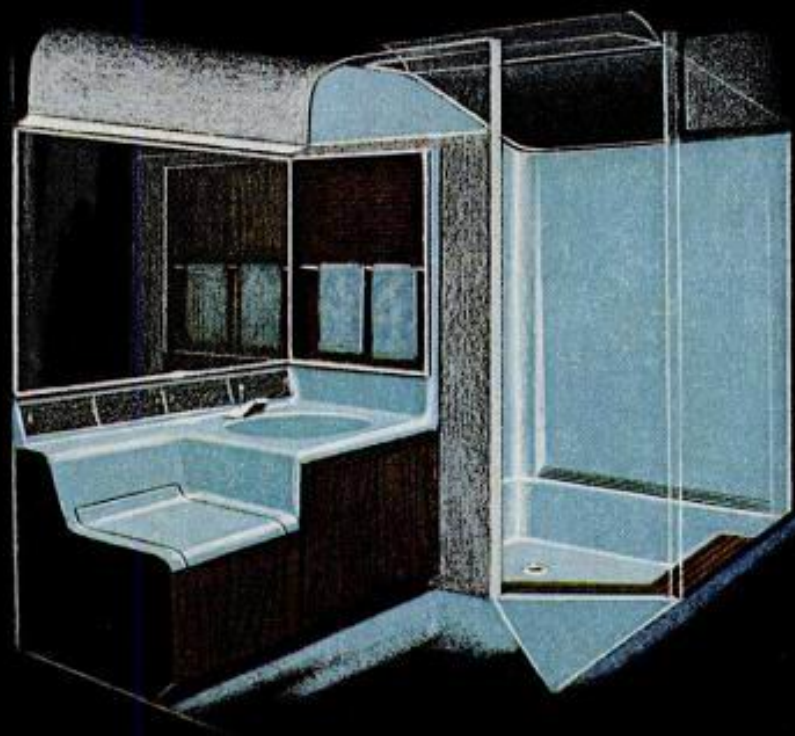
Center of action for entertaining, our kitchen is offered with a bar-height island stove and counter, U-shaped arrangement option or wall-counter with built-in standard and microwave ovens. The shallow spill-proof drawers of the refrigerator wall and tambour-enclosed shelves are handy space-savers.

Builders of large motor homes like Apollo, Landau, Executive, Barth and Bluebird are already offering microwave ovens, bars with built-in TV and other niceties. Here we go beyond to what the future can hold for travel homes away from home. ★ ★ ★

PM's motor home of the future



Command console for driver seats him behind a picture-window windshield and facing a control panel where digital readouts display miles an hour, distance remaining to campsite, miles per gallon, time and distance run, estimated time of arrival, engine temperatures and pressures on demand, gas tank levels and programmed route numbers. Pushbuttons adjust climate control, lights. Control handles can replace steering wheel.



Bathing in luxury can be a pleasing way to start and end a day of driving or camping. Single or dual-privacy compartmented bath has an adjoining sunken sauna with skylight. Split-level arrangement with raised area bedroom-lounge in the aft section of the vehicle allows generous hot and cold water supplies, and holding tanks under the rear flooring.

When you are parked for the night at a pleasant campsite, the motor home front accords out into a vertical position, driver's controls and instrument readout panel pivot down out of the way, front cushioned dash unfolds down into a couch that can later pull out to become a bed. Panel above driver's seat gives rear-viewing TV monitor picture of vehicles behind while motor home is on highway.



Rainy day and evening entertainment is easy in forward lounge-bedroom with TV or cassette movies projected from overhead closed-circuit center. For driving in fog and rain, infrared sensor might be used, aimed ahead and behind, to indicate heat-type images of other vehicles.



Central command and control center can show time, levels in all tanks, inside and outside temperatures, wind data, tape-trip monitor with projected strip map programmed to show present location. Radio and stereo include AM/FM and CB plus a TV antenna direction control, fire and intrusion alarms.



Kitchen arrangements, installed next to the dinette, can use bar or island counter stove (below) or wall counter (above) for cooking convenience en route or in camp. Both regular and microwave ovens are provided; food-preparation appliances are built in; drawer-type refrigerator and freezer pull-out shelves make selection of supplies easy and keep them secure in transit.

Trucks really are a drag. Engineers want to get rid of that drag, and they're turning to wind-tunnel testing to do it.

The reason is obvious: Less drag means more fuel economy. With the pump price of diesel fuel having doubled between 1973 and 1974, a 100,000-mile-a-year hauler can save \$1300 on even a modest 10 percent fuel-cost reduction.

Today's trucks

Many of today's trucks already have a number of gimmicks that make them more fuel-efficient: roof-mounted air dams, vortex stabilizers, faired tanks, gap seals between cab and trailer, thermatic fans, radial tires, higher axle ratios and lighter materials.

Tomorrow's trucks will go even farther into streamlining—*true* aerodynamic streamlining—to help save fuel. The boxy shapes of today will have to give way to some laid-back profiles and a lot rounder corners.

But with extremely high tooling costs for radical new designs, you

might not see the big streamliners on the highway right away. Sweeping changes always take time.

Current state of the art

Meanwhile, what's the state of the art at the moment? We already know a lot more than we can do anything about.

For example, NASA began playing around with truck shapes in 1974 and found that a 40-inch gap between a normal tractor and trailer gives 10 percent better fuel mileage than does the normal 62-to-64-inch spacing.

NASA researchers went on to test the various drag foils now on the market. They discovered that the most common roof-mounted air dam cuts drag up to 24 percent at 55 mph in still air.

A gap seal between truck cab and trailer, NASA found, reduced drag up to 19 percent.

Translated into fuel savings, the figure for both the air dam and the gap seal came to about 10 percent.

NASA then went on to another set of

experiments involving not trucks but vans. They added aluminum exterior skins to a test van—first to make it a perfect box with 90° corners. They called this Configuration A. Then NASA commenced to round off the corners and seal the underbody. Proceeding down the alphabet, Configuration E proved the best streamlined, with a three-quarter-length bellypan and all corners rounded. Drag reduction of E came to 61 percent.

This isn't to say that all drag foilers work. Nor that those that work in still air do much good when there's a side wind. Experiments have shown that some types of truck roof spoilers actually *create* drag, and that others which do some good in still air lose their efficiency when they're bucking a moderate to heavy crosswind.

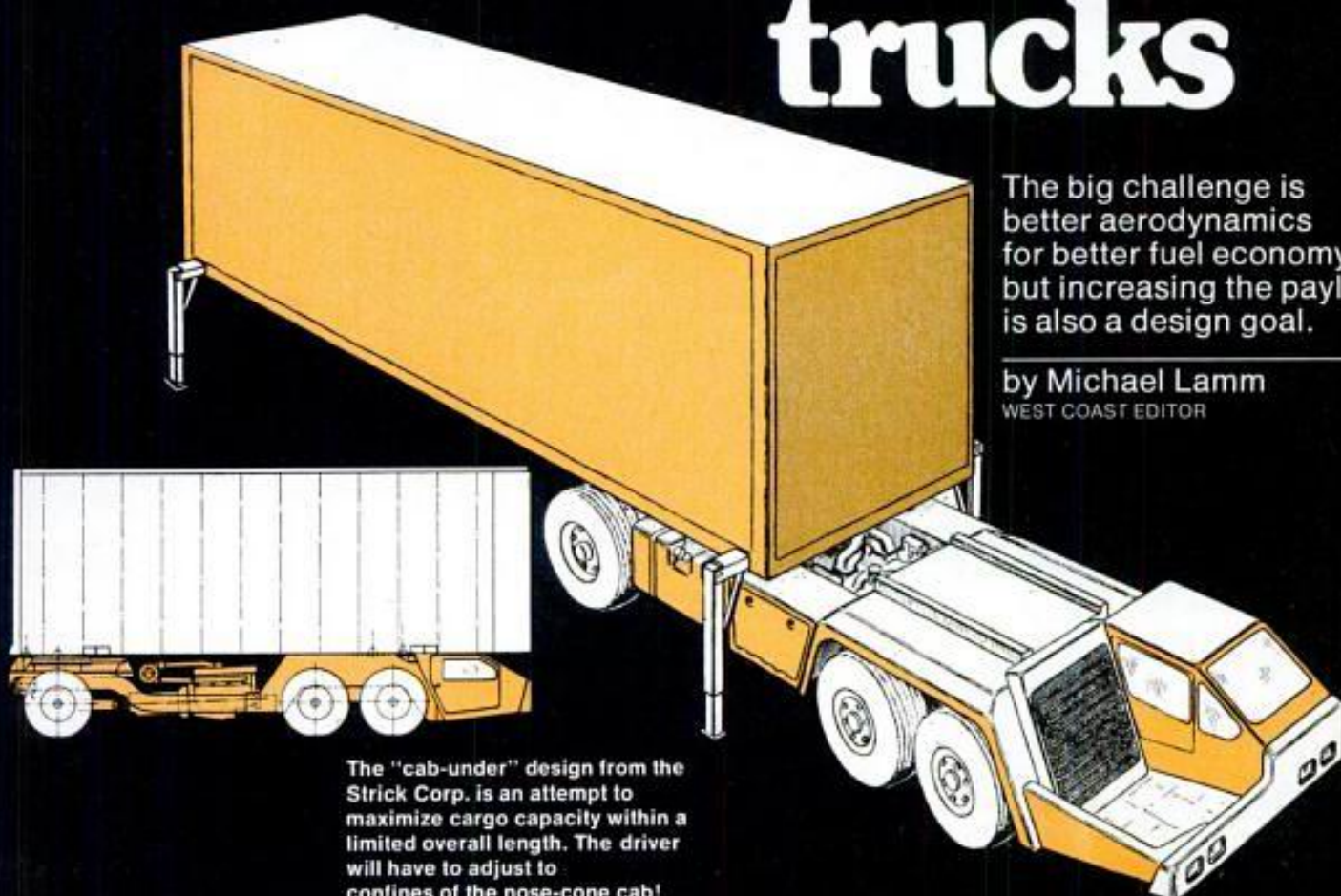
Testing on the road

One of the most ambitious and impressive recent truck streamlining experiments involves Ryder Systems, Inc., the Miami-based leasing/trucking firm. In 1974, Ryder built 10 highly

PM Previews Tomorrow's trucks

The big challenge is better aerodynamics for better fuel economy, but increasing the payload is also a design goal.

by Michael Lamm
WEST COAST EDITOR



The "cab-under" design from the Strick Corp. is an attempt to maximize cargo capacity within a limited overall length. The driver will have to adjust to confines of the nose-cone cab!

TECH UPDATE

News Of Tomorrow's Technology Today



PAUL CHARNAY

Robot Crabs Clear Surf Mines In A Pinch

ANAHEIM, CA—The surf zone. If you're riding a boogie board, you love it. If you're poised for an amphibious assault on a hostile shore, you hate it. The surf zone is a prime locale to stumble into a minefield. Not only is the water perilously shallow, but wave noise and turbidity hamper mine detection. And because a major mine-sweeping operation is sure to attract unwelcome attention, you can quickly lose the advantage of surprise.

The solution? A horde of mechanical crustaceans that can sneak in under the waves, detect mines and neutralize them en masse. Rockwell International and IS Robotics are developing these little suicide robots, or mites, called Autonomous Legged Underwater Vehicles (ALUVs). The Advanced Research Projects Agency and the Office of Naval Research are funding the effort.

The ALUV pays tribute to a crea-

ture that thrives beneath the breakers. A crab scuttles through the surf zone on legs that can dig in when the waves get rough. The Rockwell mite can also weather severe surf, burying itself in the sand by vibrating its legs.

What's more, legs are great structures to load with sensors, because they touch whatever they walk on. When the ALUV chances upon a mine, it clings to its quarry and then awaits a command from an operations center aboard a landing craft offshore. Once the signal is given, each

While an invasion force assembles offshore, autonomous legged robots walk through the surf zone hunting mines.

mite blows itself—and the mine—up.

Rockwell's prototype ALUV runs about 22 in. long and weighs 23 pounds, including 7 pounds of ballast. The mite has already proven itself capable of walking through the surf zone and finding targets. The next step, say engineers, is to build a second mite and have it communicate with the first, to make ALUV mine-sweeping more efficient.

Highlights This Month

- **Sneak Peeker**—Stealth spy drone is unveiled.
- **Power Launches**—New rockets will double Delta's lift.
- **Out There**—The quest for extraterrestrial life resumes.
- **Sun Burners**—This year's solar-car showdown.
- **Air Cushion**—Next-generation hovercraft lose weight.
- **Genetic Ink**—Sign checks with your own DNA.
- **Fat Buster**—How the Russians clean out cholesterol.

Editor/Writer: Gregory T. Pope
Reporters: Philip Chien, Chris Chinnock, Mike Fillon,
William Garvey, Scott Gourley, Barry Rosenberg

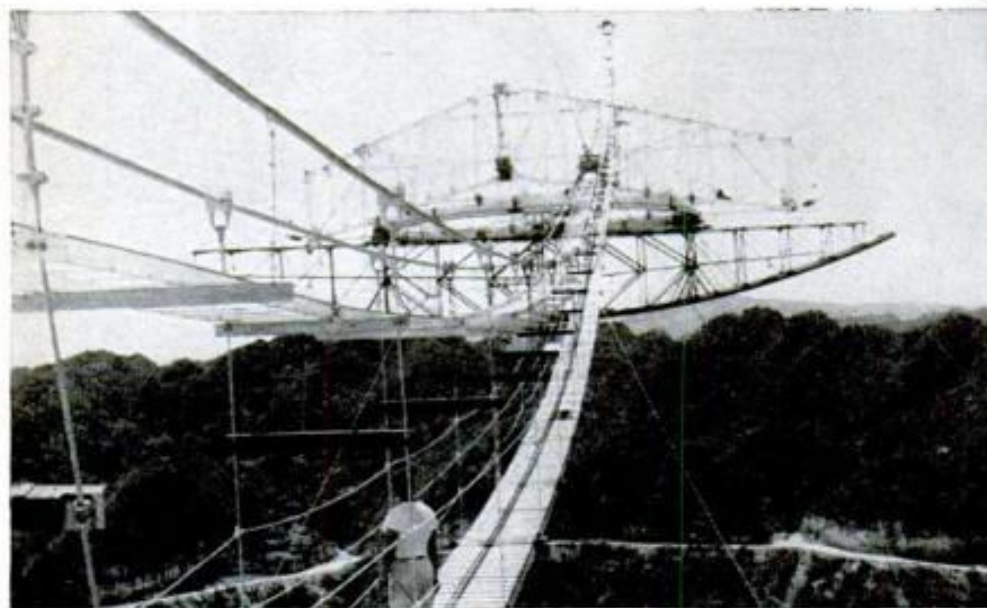
1,000-Foot Eye Starts Peering into Space

The world's biggest radar and radio telescope, a gigantic 1,000-foot-diameter reflector, has just begun exploring space. Recently completed near Arecibo, Puerto Rico, the mighty \$9,000,000 instrument is being operated by Cornell University for the Air Force Office of Scientific Research.

Targets announced for its probing radar beam include the moon, Mars, and Venus. Returning echoes will reveal variations in the nature of lunar and planetary surfaces, from place to place—yielding detailed maps that may aid in choosing landing sites for prospective space flights to other worlds. Among other tasks assigned to the huge scope, a principal one will be to study the relatively unexplored outer region of the earth's own atmosphere, the upper ionosphere, ranging from 200 to several thousand miles above the earth's surface. It will also bounce radar echoes off Mercury, Jupiter, and the sun—and, as a radio telescope, investigate the mysterious radio sources in the sky.

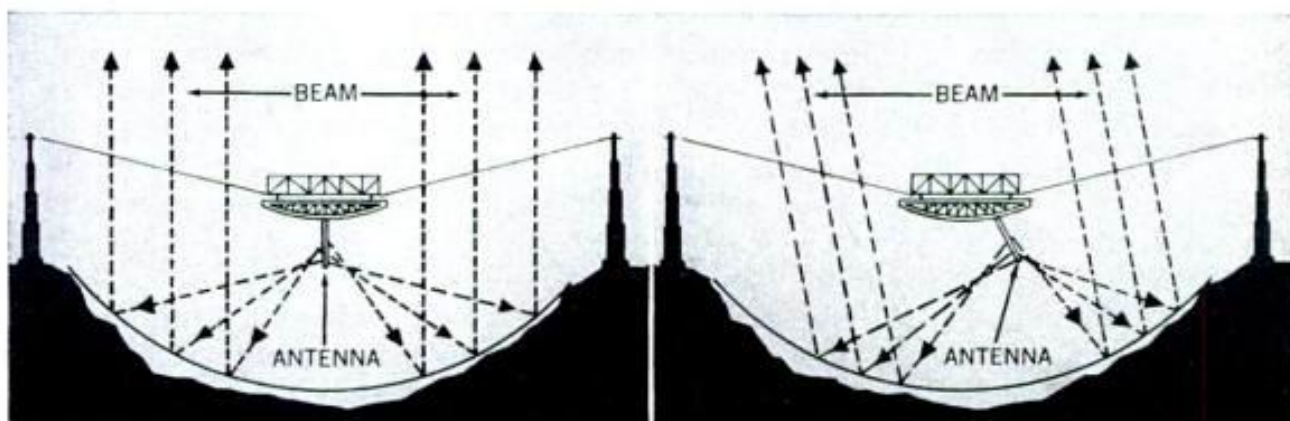
The great telescope's Puerto Rico site was chosen because it was on U.S. soil and within 20 degrees of the equator—a favorable latitude for observing the planets with a telescope of limited maneuverability. Moreover, a natural bowl at this site needed only a minimum of excavation to the desired size and shape (a portion of a spherical surface).

Lining the bowl, the scope's fixed reflector consists of wire mesh supported just above the ground on a spiderweb of cables. It projects a beam of energy from a rod-shaped antenna hanging high overhead at the bowl's focus. The antenna rides a curved track to steer the beam. By remote control, the scope is operated from a nearby 8,600-square-foot building that houses administrative offices and electronic equipment. A 430-megacycle transmitter, with peak power of 2,500,000 watts and average 150,000-watt power gives the scope the most powerful radar beam in the world.



Spectacular radar dish, in pit made from natural bowl, measures 1,000 feet across and 138 feet deep. Cables from three towers, 265 to 300 feet high, suspend transmitter-receiver carriage above its center.

Catwalk in sky leads from a mountainside to transmitter-receiver carriage, which hangs 500 feet above center of bowl. Curved bottom of carriage serves as track for scope's movable rod-shaped antenna.



Huge scope aims beam by moving antenna along curved underside of carriage suspended above its fixed bowl. With antenna over center of dish, beam points straight up (above,

left). When antenna moves away from center (right), beam is tilted, to as much as 40 degrees from vertical. To train beam in any direction, whole carriage rotates horizontally.